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Geraldine Stormwater Contaminant Load Modelling and Treatment Strategy

Timaru District Council

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Geraldine Stormwater Contaminant Load Modelling and Treatment Strategy

Prepared for

Timaru District Council

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Limitations:

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Executive Summary

The Geraldine stormwater network covers an area of 238 ha and discharges to the Waihi River, Serpentine Creek, Raukapuka Stream and Downs Creek as well as to the shallow groundwater aquifer adjacent to the Waihi River. The majority of the stormwater enters the Waihi River and Serpentine Creek with over 74 ha of land discharging to ground to the east of the Waihi River in the Raukapuka area. Key contaminants associated with the Geraldine stormwater network discharges to surface water waterways are expected to be suspended sediment, zinc and copper compounds. Bacterial contaminants are of most concern for discharges to ground where there are downstream water supplies drawn from the groundwater aquifer.

Current best practical stormwater treatment practices are unlikely to provide sufficient treatment to stormwater to meet the target levels of treatment specified in Schedule 5 of the LWRP, when there is minimal dilution from the upstream catchment flows. Therefore, a best practical option approach is required for new stormwater discharges and any upgrades where the following treatment standards are recommended:

Table 1: Recommended Minimum Target Treatment Contaminant Removal rates for Geraldine Stormwater Network[1]

Suspended Solids	> 75%
Total Zinc[2]	> 50%
Total Copper[2]	> 50 %
Total Petroleum Hydro-carbons	> 50 %
Bacteria	> 50 %

Notes:
1. *To be determined on accepted established empirical studies*
2. *Design and selection of device to consider likely dissolved metal proportion based on latest TDC investigations.*

A contaminant load model has been constructed to assist in developing a cost effective stormwater treatment strategy for Geraldine.

Sediment naturally settles in the Serpentine Creek stream channel as its grade changes from approximately 1:30 to 1:120. The highest levels of suspended sediment are anticipated to be discharged from the rural hill country upstream of the urban area. Vegetative filtration and utilisation of the existing detention dams to trap sediment are considered the most effective means of limiting sediment discharges to the Serpentine Creek.

The total sediment load discharging to the Waihi River is considered insignificant compared to the anticipated sediment load from the upstream rural catchment.

However, it is desirable to trap and limit sediment and contaminant laden stormwater discharges to all receiving waterways. Limited dilution effects are expected to occur in Serpentine Creek, Downs Creek and Raukapuka Stream for most rainfall events, which means that the stormwater discharges will have more significant effects on these waterways. Higher intensity rainfall events are likely to be diluted from runoff flows from the upstream catchment. The effects of stormwater discharges from low rainfall intensity events to the Waihi River are minimised by the existing riparian buffer between the stormwater outfalls and the low flow channel in the river. These riparian buffers should be retained and enhanced with any capacity upgrades to the stormwater network. This also provides potential to provide enhanced recreational amenity value to the river corridor.

Contaminant sampling in Serpentine Creek indicated a high levels of dissolved zinc, which poses significant toxicity risks to aquatic biota. The sources of the heavy metal contaminants are most likely related to the industrial and commercial areas if these contaminant levels are related to stormwater discharges. Where possible, soakage of first flush flows and volumes to ground is recommended to minimise discharges of heavy metal contaminants to the receiving surface water ways.

Hydrocarbons and litter are expected to be associated with accidental discharges and may be cost effectively controlled by targeting high use roads and stormwater outfalls at high profile locations.

Limited growth and significant expansion of the Geraldine stormwater network is anticipated, and space limitations are anticipated whilst fitting proposed treatment options into the existing stormwater network. Where space is limited, proprietary stormwater media filters and rain gardens offer the best potential to be retrofitted into the existing stormwater network to provide the above standards of treatment. Rain gardens potentially provide enhanced amenity, but this comes at a higher cost.

The potential exists for a large stormwater treatment wetland to cost-effectively treat flows from the Serpentine Creek catchment prior to discharge to the Waihi River. The modelling suggests that wetland treatment strategy is anticipated to provide the greatest contaminant load removal out of the options considered, with potential contaminant load removals of 75% for TSS, 50% zinc and 45% copper, in terms of total loads for the modelled CLM catchment area.

However, it is noted that such a stormwater treatment area may be of limited value if it is confirmed that Serpentine Creek has limited impact on the ecology in the Waihi River as indicated by the monitoring and ecological investigations to date.

The cost of providing best practical treatment to treat between 70-90% of the Geraldine stormwater discharges to surface water is estimated at $9.5 - $10.6M (+/-30%).

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1.0 Introduction

Pattle Delamore Partners (PDP) have been engaged by Timaru District Council (TDC) to develop a Stormwater Contaminant Load Model (CLM) and use the model to assess cost effective stormwater treatment options as part of the development of the Geraldine Stormwater Management Plan (SWMP). The findings of the report and the SWMP will ultimately be appended to TDC's resource consent application to Environment Canterbury (ECan) to permit the discharge of stormwater from Geraldine. This report details the methodology used in the CLM and the key findings and recommendations from PDP's analysis of the modelling results.

2.0 Stormwater Catchment Description

Geraldine Township is located near the base of the foothills in South Canterbury. The town is separated by the Waihi River which differentiates the main township on the western side of the river with the Raukapuka suburb on the eastern side of the river.

The Geraldine urban stormwater network covers a total area of 239 ha, of this, 164.6 ha discharge to four receiving surface waters:

- The Waihi River (46 ha, excluding Serpentine and Downs areas);
- Serpentine Creek (97 ha);
- Raukapuka Stream (7.2); and
- Downs Creek (14.3ha).

Ultimately the Serpentine, Downs Creek and Raukapuka Stream are discharge into the Waihi River.

There are also a number of discharges to ground, particularly in the urban areas to the east of the Waihi River (74.4 ha). The urban stormwater catchment area is 239 ha, as depicted in Figure 1 and Figure 2.

The urban catchment area covers a variety of land uses, including:

- Residential: 168 ha (70.3%)
- Industrial: 8 ha (3.3 %)
- Commercial: 11 ha (4.6 %)
- Parks/Reserves: 22 ha (9.2%)
- Roads and footpaths: 30 ha (12.6%)

Timaru District Council growth studies indicate that only limited growth of less than 4% is anticipated to occur in Geraldine over the next thirty years.[1]

[1] Estimate based on discussions with Timaru District Council.

3.0 Sources of Stormwater Contaminants

3.1 Common Stormwater contaminants and their effects

The following table lists the main contaminants in urban stormwater runoff.

Table 2: Anticipated Stormwater Contaminants

Contaminant	Effect
Suspended Solids	Water clarity, organic loadings and associated nutrient contaminants, concentration of inorganic contaminants, reduced light levels and loss (smothering) of flora and fauna habitat resulting in reduced aquatic life
Hydrocarbons	Oxygen depletion, aquatic life, visual
Nutrients	Excess aquatic plant growth, algal growth, oxygen depletion
Inorganics including Heavy Metals	Ecological health and biodiversity
Microbial	Human and animal health in contact with water

In order to understand the effects and quantify the impact of the potential effects it is necessary to understand the contaminant sources.

3.2 Roads and Hardstanding Areas

The most likely contaminants that may be found from roads and hardstanding areas include:

- Heavy metals such as zinc, copper (from brake linings), lead (from vehicles) and chromium (from vehicle trim);
- Hydrocarbons from leaks in the engines, vehicle transmission and exhaust fumes;
- Sediments from atmospheric deposition;
- Sediments tracked onto roads by vehicles;
- Nutrients from exhaust fumes;
- Accidental spills and occasional discharges from vehicle maintenance; and
- Litter.

Emergency discharges will originate from accidents occurring on roads. The spills will be associated with vehicle accidents resulting in spillage of hydrocarbons from ruptured fuel tanks. It is highly unlikely that the spillage of hazardous freight would occur on residential roads.

3.3 Roofs

Roof related contaminants include:

- Sediments from atmospheric deposition; and
- Metals from gutters, downpipes, roof and roof coating deterioration.

3.3.1 Atmospheric Deposition

Recent research at the University of Canterbury shows that contaminants from atmospheric deposition of sediments on residential buildings is becoming increasingly recognised as significant source of pollution in urban stormwater (Charters *et al*., 2014; Murphy *et al.*, 2014).

This is also recognised in ECan's Canterbury Land and Water Regional Plan (LWRP) (ECan, 2017) in which specific requirements are in place for stormwater discharges of water to ground in areas of high groundwater.

3.3.2 Roof Coatings

Historically, roofs in New Zealand have been predominantly galvanised iron (i.e. iron coated with zinc). Whilst this roofing material is rarely applied to new buildings in New Zealand;[2] historical data of the roofing stock composition and resultant stormwater water quality would be bias towards a higher composition of galvanised iron roofs. Due to the relative low growth rates within Geraldine, these studies are considered to be appropriate for the majority of the roofs in Geraldine.

Approximately 94% of the corrugated steel products in New Zealand are now coated with either ZINCALUME® (zinc + aluminium) or Colorsteel® (iron coated in ZINCALUME® plus a factory-applied paint coat). Further, a significant number of residential households now use tiles as their roofing material of choice (Kingett Mitchell Ltd, 2003). The use of historic data to indicate potential zinc loads in roof runoff gives a false indication as to the potential concentrations of zinc in roof runoff from new developments.

Table 3 gives an indication of likely contaminant concentrations may be found in the roof runoff. It should be noted that the concentrations of contaminants in the runoff are partly influenced by atmospheric deposition (e.g. windblown sediments, and vehicle emissions) being directly discharged to water ways instead of across ground. Hence, Table 2 below shows the concentrations of copper and lead off Colorsteel® roofs when no copper or lead roof materials are anticipated. The concentrations of atmospheric depositions are also anticipated to be related to location and proximity to industry and arterial transport routes.

[2] Various studies such as Kingett Mitchell (2003)

Table 3: Results from Roof Runoff Studies

	Copper (µg/L)	Lead (µg/L)	Zinc (µg/L)	TSS (mg/L)
Residential Roofs [1]	15	-	149	27
ZINCALUME® Roofs[2]	0.8	0.6	134[3]	12
Colorsteel® Roofs[2]	1.6	1.1	39	7
Concrete Tiles[2]	3.3	2.1	17	16

Notes:

1. *"Sources of Urban Stormwater Pollutants Defined in Wisconsin"* (Bannerman et al., 1993)
2. *"A Study of Roof Runoff Quality in Auckland" (Kingett Mitchell Ltd, 2003)*
3. *"Roof Runoff Study by New Zealand Metal Roofing Manufacturers" (Shedden et al., 2007)*

This analysis indicates that the zinc concentrations in roof runoff are expected to be significantly lower with new roofing materials compared with galvanised iron-based roofs, which would currently be the predominate roofing material in Geraldine. The data for New Zealand has been used because it is hard to compare international data to New Zealand due to different climates, and the occurrence of rain in Europe that can have a lower pH (i.e. acid rain).

Recently in some parts of the world, there has been an increased use of copper cladding and drainage fittings in architectural specifications, which would result in high copper concentrations in the stormwater, which in turn can be toxic to aquatic life.

Other contaminants present in roof runoff are likely to be atmospherically deposited fine sediments and the possibly faecal bacteria from birds sitting on the roofs.

3.4 Greenspace Runoff

Routine discharges generated from the runoff from greenspace areas, such as lawns and reserves, are likely to contain:

- Suspended sediments from erosive forces and exposed soils (e.g. during construction;
- Nutrients from decaying organic matter;
- Nutrients and bacteriological contaminants from animal leavings; and
- There may also be trace metals present, resulting from the use of sprays (pesticide/fungicide/herbicide) on residential plantings; and
- Litter.

Most of the total suspended solids (TSS) in the stormwater runoff from these areas will be as a result of construction or gardening activities where soil has been disturbed but has not settled back down or been planted before the rain arrives. Nutrients may be present as a result of fertiliser use by the landowners and as a result of faecal material from pets, particularly from public greenspace. Significant phosphorus and microbiological concentrations can be present in lawn runoff, however such levels of nutrients have not generally been observed in New Zealand stormwater quality studies.

3.5 Summary and Expected Contaminants of Concern

Urban residential runoff can be expected to contain general litter, sediment, hydrocarbons and heavy metal contaminants from road runoff. Increased vehicle movements and more direct drainage paths to waterways will increase levels of contaminants discharged to the downstream waterways.

Runoff from urban roofs is likely to discharge increased levels of metal compounds from roofing materials and drainage fittings that are potentially toxic to aquatic ecology in the downstream waterways. These impacts can be anticipated to change with architectural trends and building practices that will affect the impact of roof runoff on the downstream environment.

Increased sediment contaminants are anticipated to be discharged from roads and greenspace surfaces as well as from atmospheric deposition on roofs and buildings.

Bacteriological contamination is generally associated with runoff from both roads and green spaces picking up faecal bacteria from birdlife and pets.

4.0 Contaminant Characteristics and Water Quality Requirements

4.1 Surface water quality Requirements

Target waterway quality parameters are included in Schedule 5 of the LWRP (ECan 2017). Numerically these limits are the same as set in ANZECC (2000). Discussions with Environment Canterbury water quality staff indicate that appropriate water quality standards are defined as the 90 and 95% exceedance values of the toxicants as listed in Schedule 5 of the LWRP (ECan, 2017) for Serpentine Creek and the Waihi River respectively. These limits are based on expected catchment classifications of "hill country-lower" and "hill country lower urban".

The Opihi Regional Water Plan is the current operational resource management plan for surface water quality in Geraldine. This plan is less specific than the LWRP and requires a discharge result of no significant adverse effect from the discharge of any contaminants. The ANZECC guidelines (2000) may be used as a threshold to determine if any significant adverse effect of contaminants is likely. The standards set in the LWRP are set as trigger levels that require additional investigation to determine any adverse effects should they be exceeded. This may in the form of ecological condition of the water or bio-availability to determine if any effect on the aquatic environment is likely and or has occurred.

4.1.1 Sediment

Sediment is a very important water quality contaminant to assess and remove from stormwater.

Sediment can be associated with three different adverse effects including:

- Physical smothering effects on biota (both in the water column and on the bed substrate);
- Effects on clarity that reduce light and visibility for feeding; and
- Toxic effects from accumulated contaminants due to adhesions and/or absorption to the sediment.

Sediment may be measured directly or indirectly as the following parameters:

- Total suspended sediment (g/m^3);
- Bed sediment coverage;
- Turbidity (NTU);
- Concentration of individual contaminants by weight; and
- Indirectly as clarity or colour.

The target standards in Schedule 5 of the LWRP are only related to clarity and colour, which are both an indirect measurement of suspended solids discharged by stormwater. It is noted that the Schedule 5 targets provides requirements to limit the reduction in clarity of stormwater, which is an indirect measurement of sediment levels, however the limit does not account for variations in rainfall intensity and sediment source.

The effect of suspended sediment concentration on clarity is dependent on the physical characteristics of the sediment, specifically the particle size and composition (colour/reflectivity) of the suspended solids. The sediment particle size is also affected by sediment source, which is influenced by various factors including catchment geology topography as well as the rainfall intensity and durations. Low concentrations of fine sediment can result in a significant degradation in visual clarity in stream, compared to the same concentration of larger sediments. The smaller sized sediments in stormwater are typically sourced from atmospheric dust. While clarity is a measurable limit, it only a relative assessment against "non-contaminated" discharges and in order to design treatment systems to remove sediment and improve clarity in a water body it is necessary to have an understanding of both the likely particle size and sediment loading rates.

International studies show that stormwater sediment size (diameter) typically varies from 0.01 to 0.5 mm (Drapper, 2014). Settleability (rate of settling) of the sediment is predominantly function of sediment particle size; sediment less than approximately 0.05-0.07 mm in diameter rarely fully settles out quickly, and often passes through stormwater networks, treatment systems and into and through streams and rivers. Therefore, any bed sediment assessments, undertaken to assess the characteristics and sediment load, cannot be considered to be representative of the *full* sediment load from a stormwater discharge. However, it is representative of the proportion that may settle on the bed of the receiving waterway bed and smother habitat. Although not included in any of the current LWRP (ECan, 2017) requirements, the settleable sediment is an important measure of the effect on the permanent ecosystems. This is also a function of the waterway morphology and flow characteristics of the receiving waterway. In Geraldine, limited settlement of fine stormwater sediments occurs in the Waihi River, where the bed slope is relatively constant between 1:120 and 1:140 through Geraldine, and the channel is regularly flushed with storm and base flows from the upstream 100 km^2 catchment. Significant sediment settlement will naturally occur in the Serpentine Creek where the bed-slope changes from 1:30 downstream of the Hislop Street flood detention dam on the slopes of Talbot Forest to 1:120 upstream of the confluence of the Waihi River, and sediments are retained by the vegetated channel.

Owing to the complexities of defining a single limit for the various effects of sediment discharged with stormwater, requirements for sediment treatment for stormwater are commonly expressed as a treatment removal rate, rather than a specific limit. A suspended solid removal rate of 75% is considered good practical removal rate based on international studies of commonly used stormwater treatment devices.

4.1.2 Heavy Metal Contaminants

Based discussions with ECan Limits from the principal main heavy metal contaminants in stormwater for the receiving waterways, being zinc and copper, are shown in Table 4 below.

Table 4: Zinc and Copper Water Quality Limits for Geraldine

Level of Protection (% of species)	Zinc	Copper
90% species (Serpentine Creek, Downs Creek, Raukapuka Stream)	8 mg/m^3	1.4 mg/m^3
95% species (Waihi River)	15 mg/m^3	1.8 mg/m^3

The contaminants are considered more toxic in their dissolved form (in solution). As sediments are an important source and sink of dissolved contaminants, it is therefore prudent to assess and evaluate the concentrations present in sediments within the Geraldine creeks and stream, compared to ANZECC (2000) interim sediment quality guideline (ISQG) values, listed in Table 5. When the low trigger levels are exceeded, further investigations are required, which may be in the form of bio-availability or ecological investigations, to determine if there is any likely effect on the condition of the waterway.

Table 5: Recommended Sediment Quality Guidelines for Heavy Metal Limits in Geraldine Streams and Creeks

Tigger Value	Zinc	Copper
Low ISQG [1] Trigger	200 mg/kg	65 mg/kg
High ISQG Trigger	410 mg/kg	370 mg/kg

Notes:

1. *ISQG = interim sediment quality guideline (ANZECC 2000)*

4.1.3 Hydrocarbon Contaminants

Hydrocarbons are organic compounds consisting entirely of hydrogen and carbon. In stormwater, the hydrocarbons of concerns can be summarised into three distinct groups:

- Phytogenic hydrocarbons – are found in stormwater, the principal sources of phytogenic hydrocarbons are leaves and other plant material, and decomposing organisms (e.g. invertebrates, fish and birds). Phytogenic hydrocarbons are therefore, most abundant in runoff from forested, rural and suburban catchments, and least abundant in stormwater from industrial catchments.

- Petrogenic hydrocarbons – occur in stormwater generated on roads, at petrol or fuelling stations and industrial sites handling hydrocarbons are likely to be the largest sources of petrogenic hydrocarbons. Other sources include tyre abrasion, and erosion of bitumen. Coal-derived hydrocarbons are possible if coal is mined or transported.

- Pyrogenic hydrocarbons – are present in stormwater, sources include soot from fires (both wood and coal fires), coal tars and vehicle exhausts. As a result, petrogenic hydrocarbon concentrations are typically higher in stormwater from urban catchments than in rural and forested catchments.

Very limited guidance is provided in ANZECC (2000) and Schedule 5 of the LWRP or any international studies with respect to acceptable levels of total hydrocarbons in stormwater discharges and where available, limits vary between the various individual compounds, so it is very difficult to provide limits due to both the number of individual compounds involved and limits in the science of their effects.

Some guidance is provided in ANZECC (2000) and Schedule 5 of the LWRP and international studies with respect to acceptable levels of hydrocarbons in stormwater discharges; for example, the LWRP provides limits for individual aromatic hydrocarbons such as benzene. However, such limits differ for the individual compounds, and therefore it is difficult to provide an overall limit for hydrocarbons or polycyclic aromatic hydrocarbons (PAH) given the variety of different compounds and knowledge of their effects.

It is noted that hydrocarbons adhere and accumulate on sediments; ANZECC (2000) provides recommended sediment quality trigger values for Total Polycyclic Aromatic Hydrocarbons (PAH) as well as various hydrocarbon compounds.

PAH's are a major class of priority hydrocarbons found in stormwater and their main source is from vehicle exhaust particulates, vehicle oil loss and other organic combustion products, which settle out in the atmosphere and are washed into the stormwater system.

PAH's can also be associated with coal tar based bitumen products that have been historically used to tar seal roads, and studies in both Auckland and Christchurch indicate that coal tar based seal coat can be a significant source of PAH pollutants, especially when it is disturbed.

Table 6: Total PAH Trigger Values – Sediment Quality Guidelines for Geraldine	
Low ISQG Trigger	4,000 mg/kg
High ISQG	45,000 mg/kg

4.1.4 Bacterial Contaminants in Surface Water

Escherichia coli (*E. coli*) is a bacterium that is well established as an indicator organism associated with the presence of faecal contamination from warm blooded animals (and/or humans). The water quality requirements defined in Schedule 5 of the LWRP (ECan 2017) is greater than 95% of all water quality samples shall contain less than 550 *E.coli* cfu/100 ml for both "hill fed- lower" and "hill fed – urban" classifications considered applicable to the Waihi River and Serpentine Creek respectively. This is in line with the proposed NPS standards for freshwater, which specifies a maximum acceptable guideline value of 540 *E. Coli* cfu/100 ml.

The water quality records for the Waihi River currently has a median value of less than 130 *E. Coli* cfu/100 ml and meets the LWRP. In addition, no change in *E. coli* levels is reported upstream and downstream of Geraldine. Current swimming classification maps do not show any change in the level of bacterial contamination in the Waihi River upstream and downstream of Geraldine township.[3]

[3] As per *Water quality for swimming in Canterbury Region* maps (MfE, http://www.mfe.govt.nz/fresh-water/about-freshwater/canterbury, accessed 16 March 2017)

4.2 Groundwater Quality Requirements

Groundwater water quality requirements are developed to protect human health, specifically in maintaining safe drinking water standards. Groundwater contamination of stormwater has not been historically recognised as a major pollutant of groundwater (PDP, 2013). The US Environmental Protection Agency (USEPA, 1993) reports that the metals in stormwater can be mostly removed by either the sedimentation or filtration processes, as the water percolates into the groundwater. In addition, the metals don’t tend to be particularly mobile in groundwater. Generally heavy metals found in stormwater are also less than the maximum acceptable values (MAV) in the New Zealand Drinking Water Standard (DWSNZ 2008).

Bacterial contamination presents the greatest threat of non-compliance of groundwater water quality; the DWSNZ (2008) requires less than 1 *E. coli* in a 100 mL sample.

4.3 Summary

The most likely effects of stormwater discharges from urban areas on the water quality of the downstream water ways are:

- Sediment affects water clarity and aquatic life including downstream deposition of sediment. There are no trigger values for TSS; owing to the importance and the complexities of defining the impact of sediment, a target good practical treatment of at least 75% removal of sediment is recommended. Schedule 5 of the LWRP (ECan 2017) also provides target requirements to limit the reduction in clarity of stormwater, which is an indirect measurement of sediment levels but does not account for variations in rainfall intensity and sediment source.
- Heavy metals (copper, zinc and lead) can in high concentrations adversely affect aquatic ecology. Based on previous studies (discussed earlier in Sections 3.0-4.0) these are anticipated to be present at concentrations higher than the ANZECC trigger values. These heavy metals have defined limits defined in Schedule 5 of the LWRP (ECan 2017) and associated trigger values (ANZECC 2000) that are accepted as presenting a potentially toxic risk to aquatic life.
- Faecal Coliforms affecting recreational activities in the downstream waterways especially following rainfall. Both Schedule 5 of the LWRP (ECan 2017) have similar maximum acceptable limits for recreational use.
- Accidental discharges of litter, oils and other contaminants causing visual impacts and clarity issues (as noted in Section 3.0).
- Groundwater water quality standards have been prepared to protect and provide safe ground sourced drinking water, which have stringent limits

on the presence of *E. coli*, an indicator bacterium associated with faecal contamination.

- Limited adverse health effects are anticipated from heavy metal contaminants in groundwater

There are considerable uncertainties relating to the of the actual effect(s) of discharges on the environment, owing to the variability and intermittent nature of the discharges, the degree of mixing that will occur downstream of any surface and/or ground discharge, and cumulative effect(s).

However, the above figures (Sections 3.0 and 4.0), which are based on a number of international and national studies, show that contaminant levels higher than accepted maximum acceptable standards are anticipated to be discharged from urban stormwater.

5.0 Method of Assessment of Stormwater Treatment Requirements

5.1 Contaminated Load Model

The Geraldine CLM is based on the Serpentine Creek CLM developed by Opus (2014) Opus. The Serpentine Creek model itself is a modified form of the Auckland Regional Council's CLM (ARC, 2010). The Opus model only considered total contaminant loads discharged to Serpentine Creek and did not allow for contaminant loads discharged directly to Downs Creek, Raukapuka Creek or the Waihi River.

Therefore, the CLM was updated by PDP to account for the stormwater contaminant loads received by all the significant receiving waters. In addition, the CLM has been used to identify and evaluate the most cost effective contaminants treatment systems (and locations) to result in a material improvement in the water quality of the receiving waterbody.

The CLM, as shown in Figure 3, includes the following areas:

Table 7: CLM Modelled Areas

Catchment	Contributing Area
Raukapuka Stream	7.2 ha (total urban area = 81.6ha)[1]
Serpentine Creek	221.7 ha (total urban area = 97ha)
Downs Creek	Not included
Waihi River	52.9 ha (total urban area = 46 ha)

Notes:
1. *74.4 ha discharged to ground not modelled*

Discharges to Downs Creek were not included in this revised CLM, given the small area of this sub-catchment and therefore the small contaminant load this catchment would contribute, specifically due to the catchment being predominantly rural. It is noted that the modelled Serpentine Creek area however includes some rural areas, in particular forested areas towards to the north-west and rural areas towards the south of the modelled area (as shown in Figure 3).

The CLM is based upon categorizing the different *surface types* for each land use within the catchment of interest. Each *surface type* is assigned a contaminant loading rate, and the overall contaminant load is obtained from multiplying the surfaces areas by the corresponding loading rate (expressed g/m^2/yr). The main contaminants of concern modelled in this study are total suspended solids (TSS), zinc, copper and total petroleum hydrocarbons (TPH). Loading rates used in the current study are derived from those used in the previous Serpentine CLM (Opus, 2014). The current CLM model was developed as outlined in the steps below:

1. PDP (2017) catchment areas were imported into ArcMap.
2. The Opus (2014) Serpentine Creek land use areas were imported into ArcMap and adjusted where appropriate. Remaining areas were classified by land use type to provide land uses for all catchment areas that drain to the Waihi River, Raukapuka Stream, and Serpentine Creek. A map showing the land use composition is provided in Figure 3.
3. Using ArcMap, a spatial overlap was performed to calculate the land use areas for each contributing area (sub-catchment), as shown Figure 3 and Figure 4. The results were subsequently exported as a CSV file.
4. The CSV file was imported into Excel, and areas of surface type were calculated for each sub-catchment. Using contaminant loading rates previously developed for the Serpentine Creek CLM (Opus, 2014), contaminant loads were calculated for each sub-catchment by multiplying the surface area types by the corresponding contaminant loading rates. Sub-catchment contaminant loads were also calculated as a percentage of the total catchment loads. Note: the calculated loadings are not cumulative (e.g. the contaminant load for Catchment Area 17 does not include the loading from Catchment Area 16).
5. The results from Step 4 were imported into ArcMap to generate contaminant loading maps for TSS (Figure 5), zinc (Figure 6), copper (Figure 7), and TPH (Figure 8).

5.2 CLM Limitations

The ARC CLM (ARC 2010) was developed for the Auckland region. It has been widely applied in other parts of New Zealand, however with limited success, mainly due to yields for TSS which are unlikely to be accurate for rainfall and soils that differ from those found in the Auckland setting. Nonetheless, the chemical contaminants predicted by the ARC CLM should be reasonably applicable to most urban areas of New Zealand (ARC, 2010).

In addition, the ARC CLM has not been calibrated for catchments containing rural land. Whilst rural areas, relative to urban land, generate negligible quantities of zinc, copper and TPH, they can contribute substantial amounts of TSS from pervious surfaces. ARC (2010) note that catchments with greater proportions of rural land will have higher uncertainties associated with the predicted TSS loads. To minimise this uncertainty, ARC recommend that the CLM model should only be applied to areas where the total area of rural land is less than approximately 20% of the catchment area (ARC, 2010). The catchment modelled in this current study has approximately 30% rural cover (pasture and forest areas), and therefore there may be significant uncertainties in the TSS loadings from these areas.

It is noted that the ARC CLM also predicts contaminant from the erosion of stream channels. However, this current study focuses on the contaminant loads from urban areas in Geraldine, and therefore stream channel erosion has not been included in this assessment.

The distribution of roof material types has been assumed to be same as the distribution employed in the Opus model, which is based upon roof material distributions described in Appendix A of the CLM User Manual (ARC, 2010). This is based upon a roof survey undertaken in the Auckland region; therefore, if the Geraldine roof distribution is significantly different, there may be errors in the zinc and copper loading rates.

The contaminant loading for paved surfaces (paves surfaces other than roads) has been taken as those employed by the Opus model. These loading rates were derived from the ARC CLM calibration, and are suitable for large urban catchments with around 10-30% paved surfaces (ARC, 2010). For this current study, the catchment area has approximately 7% paved surfaces, and therefore contaminant loading assumptions for paved surfaces are expected to be reasonably appropriate.

The largest errors in CLM result may occur when some source areas are not known and the source area fractions are not appropriate for the particular catchment being modelled or of the connectivity runoff flow paths is not fully understood.

Modelled contaminant loads have been found to differ by ±20% for TSS, ±35% for total zinc and ± 25% for copper for application in the Auckland region. Thus some discretion is required when interpreting the results (ARC, 2010). The purpose of the current contaminant load modelling is to identify 'hot spots' for contaminants, and assist with identifying areas where stormwater treatment is most appropriate and effective.

In addition, sub-catchments used in this current study are those derived by PDP; limitations relating to the sub-catchment boundaries are discussed in the 2017 PDP Preliminary Infrastructure Capacity Assessment report (PDP, 2017).

5.3 Scenarios Modelled

The only development scenario modelled in this assessment is the current scenario (based on 2013 aerial imagery and associated District Plan planning zones).

A map showing the land use areas for the current scenario used for the CLM is provided as Figure 3, Appendix A.

This approach is suitable due the low growth rates anticipated for Geraldine, being 4% over the next thirty years.

5.4 Stormwater Treatment Options

The applicability and cost effectiveness of various stormwater treatment devices to remove stormwater derived contaminants is examined. This involves an examination of the practicalities to install the different treatment devices and their cost effectiveness to reduce the contaminant load.

Cost curves were developed for capital costs, land requirements, maintenance costs and whole life costs to enable the most cost effective and practical stormwater treatment options for the Geraldine stormwater network.

5.5 Stormwater Treatment Strategies

Utilising the CLM and the treatment options results enables scenarios to be developed and modelled in order to develop cost effective strategies to reduce the contaminant load from the Geraldine Stormwater Network. These can subsequently be considered against the environmental benefits and objectives in the Geraldine Stormwater Management Plan.

6.0 Contaminant Load Model (CLM) Results

Figure 3 depicts the land uses derived as inputs to the CLM, and Figure 4 shows the catchment areas (contributing areas) for which contaminant loads have been calculated. The source contaminant loads, expressed as a percent of the total CLM load, are summarised below in Table 8 to Table 11 for the entire study area, the Waihi, Serpentine and Raukapuka catchments respectively. Contaminant loads for each contributing area, expressed in kg/yr and as a percent total of the catchment, is summarised in Table B1 in Appendix B.

The entire study area, as shown in Figure 3 and Figure 4, includes discharges to the Waihi River (52.9 ha), Serpentine Creek (221.7 ha) and Raukapuka Creek (7.2 ha).

The Waihi River has a total upstream catchment area of over 10,000 ha, compared with the Geraldine urban area of 46 ha.[4] Raukapuka stream has a catchment area of over 820 ha at Geraldine compared with an urban area of 7.2 ha which discharges directly to the Raukapuka stream (i.e. excluding areas that discharge to ground via infiltration).

No attempt is made to define the rural catchment contaminant loads from the Waihi or Raukapuka catchments. Owing to the magnitude of these catchments, this would be best estimated using regional sediment studies rather than the Auckland CLM loading rates. However, the contaminant loads from the upstream catchments is beyond the scope of these investigations.

[4] The Waihi catchment urban area indicated (46 ha) does not include Serpentine Creek or Raukapuka Stream sub-catchment areas, and excludes grass, forest, rural and lifestyle land use categories.

Table 8: CLM Results – Sources of Contaminants for Entire CLM Study Area

Zone	TSS	Zinc	Copper	TPH
Commercial	0.4%	24.0%	16.0%	0.0%
Footpath	0.2%	2.7%	5.9%	0.0%
Industrial	0.2%	37.3%	18.0%	0.0%
Road < 1k	1.6%	0.9%	3.4%	23.5%
Road 1k - 5k	1.2%	2.8%	11.1%	76.5%
Rural	87.3%	8.6%	18.9%	0.0%
Residential	9.2%	23.6%	26.7%	0.0%

Notes:

1. *The above results summarise the contaminant loads for the entire study area, covering an area of 281.7 ha, as shown in Figure 3 to Figure 8, which includes rural, urban and forest areas*
2. *Results are expressed as a percentage of the total catchment load.*

Table 9: CLM Results – Source of Contaminants for Serpentine Creek CLM Catchment

Zone	TSS	Zinc	Copper	TPH
Commercial	0.2%	11.9%	9.0%	0.0%
Footpath	0.2%	3.7%	8.0%	0.0%
Industrial	0.2%	46.8%	22.5%	0.0%
Road < 1k	1.1%	0.7%	2.8%	27.7%
Road 1k - 5k	0.6%	1.8%	7.2%	72.3%
Rural	90.0%	10.6%	23.1%	0.0%
Residential	7.6%	24.4%	27.4%	0.0%

Notes:

1. *The above results summarise the contaminant loads for the Serpentine Creek catchment area, as shown in Figure 3 to Figure 8, which includes rural, urban and forest land uses, covering an area of 221.7 ha. The urban area is approximately 97 ha.*
2. *Results are expressed as a percentage of the total catchment load (including the upstream rural area)*

Table 10: CLM Results – Source of Contaminants for Waihi River CLM Catchment

Zone	TSS	Zinc	Copper	TPH
Commercial	1.6%	61.8%	38.1%	0.0%
Footpath	0.0%	0.0%	0.0%	0.0%
Industrial	0.1%	11.2%	5.6%	0.0%
Road < 1k	4.2%	1.0%	4.3%	14.8%
Road 1k - 5k	5.3%	6.0%	24.5%	85.2%
Rural	71.5%	3.2%	7.7%	0.0%
Residential	17.3%	16.7%	19.8%	0.0%

Notes:

1. *The above results summarise the contaminant loads for the Waihi River catchment area, which covers an area of 52.9 ha and excludes contributions from the Serpentine Creek and Raukapuka catchment. Land uses include urban and lifestyle blocks. Urban areas make up 46 ha.*
2. *Results are expressed as a percentage of the total catchment load.*

Table 11: CLM Results – Source of Contaminants for Raukapuka Stream CLM Catchment

Zone	TSS	Zinc	Copper	TPH
Commercial	4.3%	1.0%	15.7%	0.0%
Footpath	0.0%	0.0%	0.0%	0.0%
Industrial	0.0%	0.0%	0.0%	0.0%
Road < 1k	24.3%	5.5%	14.5%	100.0%
Road 1k - 5k	0.0%	0.0%	0.0%	0.0%
Rural	0.0%	0.0%	0.0%	0.0%
Residential	71.5%	93.5%	69.7%	0.0%

Notes:

1. *The above results summarise the contaminant loads for the Raukapuka Stream catchment area, as shown in Figure 3 to Figure 8, where discharges occur directly to the Raukapuka (i.e. excluding discharges to ground via infiltration). Covers an urban area of 7.2 ha and excludes contributions from the Serpentine Creek and Raukapuka catchments.*
2. *Results are expressed as a percentage of the total catchment load.*

6.1 Total Suspended Solids (TSS)

The CLM predicted source of TSS by catchment as a percentage of the CLM TSS load are shown in Figure 5. Serpentine Creek has an upstream hillside rural catchment of 88.8 ha (contributing Catchments 165 and 16), and the highest source of TSS load is predicted to occur in these upper catchments. The predominant land uses in these areas are forests and pasture. In addition, the CLM indicates high TSS loads in the lower catchment, where the predominant land uses are grass and pasture, with some residential and rural lifestyle land uses. These results are to be expected, as these areas are predominantly rural, with higher exposed (pervious) surface areas.

6.2 Heavy Metal Contaminants

6.2.1 Zinc

The CLM assumes that the highest zinc contributions come from galvanised steel roofs, and to a lesser degree from vehicle tyres. Therefore, areas with the highest degree of galvanised steel roofs are predicted to have the highest zinc loadings, namely commercial and industrial areas, and to a lesser degree residential and road areas.

The results, as shown in Figure 6, show the highest zinc contribution comes from Catchment 4, which contributes 18.7% of the total zinc load and has a 5.6 ha catchment area. Catchment 4 is predominantly industrial, and is bound by High Street and Talbot Street on either side.

The CLM indicates high zinc contributions from Catchment 8_126_128, with 7.8% of the total zinc load and a catchment area 10.5 ha which is bound by Huffey Street and North Terrace Road. Catchment 121 (Cross Street) contributes 7.7% of the total zinc, with a catchment area of 6.6 ha. Both Catchments (8_126_128) Huffey Street /North Terrace area (8_126_128) and Cross Street (121) contain industrial areas which contribute to the high zinc loads.

Other large catchments that contain residential areas and road areas (e.g. Catchment 0, towards the southern end of the catchment) are also predicted to generate higher proportions of the catchment-wide zinc load.

6.2.2 Copper

The CLM assumes that the main contributors to copper loads are copper roofs and vehicle brake pads. The contaminant loading rates derived by Opus (2014) and employed in this study assumes a roof material split as outlined in ARC CLM User Manual (ARC, 2010) in Appendix A: Model Inputs (Tables A.2 – A.4), which assumes that 1% of commercial roofs (and/or gutters) are copper. This assumption is yet to be verified for Geraldine. Therefore, the highest yields are predicted from commercial areas, associated mainly with copper roofs, as well as industrial areas, associated mainly with paved surfaces (from vehicle brake pads and discs), as well as roads. As such, copper loads are generally anticipated to be greatest in commercial and industrial areas.

The copper results, shown in Figure 7, indicate that copper contributions are high in urban areas, linked to roofs, paved areas and roads. Highest contributions are indicated from catchments with greater proportions of industrial areas, such as Catchment 4, which is located between High Street an Talbot Street and is modelled as contributing 10.1% of the catchment copper load (high loads are also predicted for catchments 121 (Cross Street, 4.5%) and 8_126_128 (Huffey Street/North Terrace, 5.2%), which both include industrial areas. The CLM also predicts high contributions from large rural catchments that contain residential and road areas, such as Catchments 0 (5.5%, rural land, lower Serpentine Creek, 31 ha), 16 (6.1%, Peel Detention Basin catchment, 33 ha) and 112 (4.0%, south-eastern end of Serpentine catchment, 17.1 ha).

6.3 Total Petroleum Hydrocarbon Contaminants

The CLM assumes that total petroleum hydrocarbons (TPH) are only generated from road surfaces. Therefore, loadings of TPH are greatest for sub-catchments containing the largest proportion of road areas. As such, the manner in which sub-catchments are delineated will affect the TPH loading. As shown in Figure 8, the highest TPH contributing areas are expected to occur in catchments that contain portions of the busiest roads (Cox Street and Talbot Street); approximately 76% of the TPH load is derived from such roads. Therefore, to have the greatest effect on TPH removal, stormwater treatment should target road runoff from these road areas.

7.0 Summary of CLM Modelling

The preceding sections of this report presented the anticipated sources of contaminant loads for heavy metals (zinc and copper), TSS and TPH resulting from existing land uses in the Geraldine area. The CLM results indicate that:

- A large proportion of the CLM TSS loading originates from the upstream forested slopes towards the north-east of the catchment (Catchments 165 and 16, which collectively contribute 63% of the total TSS load);
- The sediment loadings entering the Waihi River are considered to be insignificant compared to those upstream of the Geraldine catchment;
- Approximately 77% of the TPH load originates from the highest trafficked roads such as Cox Street and Talbot Street;
- Zinc and copper loads are generally highest in industrial and commercial sub-catchments;
- Contaminant load contributions to receiving waterways from Raukapuka urban areas are minimal compared to the catchment totals;
- Whilst not included in the CLM, Downs Creek urban area contributions are similarly anticipated to be minimal compared to the total catchment. Some local effects on the aquatic environment may be anticipated in the immediate vicinity of the point of discharge; where dilution of first flush runoff is expected to be minimal.

8.0 Additional Contaminant Loading Considerations

8.1 Changes in Contaminant Loads

Limited growth is expected in the Geraldine Township; however, there exists some capacity to upgrade the Geraldine stormwater network. Therefore, the majority of the stormwater runoff will continue to drain through existing discharge points and a lot of future development will be through infill of existing drainage catchments. The available space to retro-fit stormwater treatment devices in the existing drainage catchments will be a major factor determining the ability and costs to reduce related contaminants.

PDP (2017) showed that the Geraldine stormwater network has limited capacity in many places. Upgrades to improved drainage are expected to lead to an increase in direct discharges of contaminants to the receiving waterways. For example, areas that previously drained to the waterways via overland flow may instead become piped and discharge from an outlet. A decrease in the proportion of discharges via overland flow could potentially lead to increases in the real contaminant loads reaching the waterways (due to loss of the indirect treatment via vegetation or to ground) should appropriate stormwater treatment not be provided. Consequently, it is important to provide suitable stormwater treatment devices with any capacity upgrades that may increase contaminant load discharges directly to the receiving waterways.

8.2 Direct Discharges from Serpentine Creek

Owing to the topography of Serpentine Creek, with a number of incised channels into the base of Talbot forest and its surrounding hillside, a number of private property discharges occur directly to the nearest water way and do not occur through any public stormwater network. Timaru District Council does not have any responsibility for these connections other than through the building consent process.

Stormwater treatment is not considered practically achievable for runoff originating from these areas without voluntary efforts from the individual property owners. Figure 9, Appendix A, depicts these likely areas, which in total add up to approximately 16.5 ha, equivalent to 7.5% of the total Serpentine catchment area (and approximately 17% of the urban Serpentine catchment area). With respect to contaminant loads, this means that for some sub-catchment areas a significant portion of contaminants loads will not be able to be treated through the Geraldine stormwater network. Nonetheless, for the Serpentine catchment as a whole, the CLM model suggests direct discharges account for 3.1% of TSS, 7.6% of zinc, 6.8% of copper and 1% of TPH urban stormwater contaminant loads into Serpentine Creek. Table B19, Appendix B, itemises the direct discharges of contaminants to Serpentine Creek.

8.3 Dilution Effects

Minimal dilution effects are expected in Serpentine Creek, which only appears to have base flows during and after periods of heavy rain.

However, owing to the riparian buffers in the Waihi River, significant discharges of contaminants to the receiving waterway's aquatic environment are anticipated to be largely limited to heavy rainfall events, when significant dilution of the stormwater discharges is expected to occur from the upstream rural catchments. Notwithstanding, minimal dilution of contaminants is anticipated during a high intensity summer time thunderstorm when stormwater flows are anticipated to receive minimal dilution from flows in the Waihi River.

8.4 Sedimentation Effects

Sedimentation occurs with changes in velocities causing sediment to be settled out as the water way reduces in slope or flow and does not have the energy to transport the sediment downstream.

Limited settlement of sediment is anticipated in the Waihi River and Raukapuka Stream owing to limited changes in slope of the floodplain in the vicinity of Geraldine. Sedimentation in the Waihi River is generally limited to gravel sediment in main channel and silts in the vegetative riparian buffer. Flows and their associated velocities from the much larger upstream catchment generally maintain velocities and keep the low flow channel free of settled fine sediment.

The streambed slope of Serpentine Creek changes significantly through Geraldine (from 1: 30 to 1:120) and there is limited upstream flows to flush any fine sediments along the waterway.

9.0 Water Quality Status

9.1 Water quality sampling completed to date

As part of a resource consent application for a global stormwater resource consent application on behalf of the Timaru District Council, PDP is currently preparing an assessment of environmental effects which includes a description of water quality sampling completed to date in the Waihi and Serpentine, summarised below.

9.1.1 Serpentine Creek Surface Water Quality

Available water quality monitoring data is limited to two studies from Opus (2013) and an October 2016 investigation by PDP, which provide data representing winter and spring conditions respectively.

Results from both the Opus (2013) and PDP (2016) survey indicate that Cu and Zn levels within Serpentine Creek baseflows are elevated, with exceedances of the ANZECC 90% and 95% species protection trigger values. The majority of these metals consisted of dissolved metals and the fraction of dissolved Zn at the Geraldine Domain within Geraldine Township could potentially present a significant toxicity risk to aquatic biota, especially if the elevated concentrations are not naturally sourced. It has yet to be definitively established if these levels of metals are related to stormwater discharges or are due to the natural baseline condition of the waterway.

Nutrients are elevated throughout Serpentine Creek, and were observed to increase downstream as potential agricultural inputs are present. The adjacent agricultural land downstream of Geraldine Township is almost entirely unfenced and there is further evidence of possible effects from localised run-off and stock access along this section of Serpentine Creek.

Other water quality parameters analysed outline that Serpentine Creek has an excessively enriched (TP) and enriched (TN) nutrient condition, with biologically available nutrients reducing due to excessive macrophyte growth, and greater *E.coli* values indicating increased levels of faecal coliforms at downstream sites.

Ecological monitoring by Opus (2013) and PDP (2016) indicated a low water quality based on MCI and QMCI indices.

9.1.2 Waihi River Surface Water Quality

The PDP (2016) and Opus (2013) surveys did not detect any exceedances of ANZECC (2000) 95% trigger values for heavy metals in the Waihi River, with the majority of total and dissolved metals below detection limits. Similarly TPH was below detection limits, and concentrations of NH_4-N and nitrate-N did not exceed any of the guideline values (ANZECC 2000; Hicket, 2013; NPS-FM 2014).

9.1.3 Waihi River Ecological Data

PDP (2016) undertook an ecological investigations in October 2016, which included aquatic macroinvertebrate sampling at three sites on the Waihi River; the sites were located upstream of Geraldine, within the vicinity of the Geraldine Township, and downstream of the Serpentine Creek confluence. In general, the downstream site scored lowest MCI and QMCI values, followed by the Township and upstream sites. Higher MCI and QMCI values were found for the upstream site, indicating "good" quality. No significant reduction in quality was observed in the Waihi River downstream of Serpentine Creek. Opus (2013) undertook ecological assessments at two locations in the Waihi River (upstream and downstream of the Geraldine Township). The sampling at both locations was considered to indicate "good" to "high" ecological health. As there were limited differences in the chemical composition of the water quality, differences between the Opus (2013) and PDP (2016) ecological assessments are considered to be more likely to be related to differences in the flow regime rather than any effects from any stormwater discharges.

9.1.4 Other Catchments

No water quality sampling data has been undertaken for the Raukapuka or Downs Creek. The CLM modelling results indicate that the Raukapuka urban area (as shown in the Appendix A figures) contributes approximately 1% of the total TSS load, 1.6% zinc, and 2.5% copper.

10.0 Treatment Device Options

Left untreated, the discharge of stormwater will involve discharge levels of contaminants in excess of the levels defined in Schedule 5 of the LWRP and has the potential to have an effect on the aquatic life on the receiving environment that is greater than minor. Therefore, consideration must be given to appropriate stormwater treatment options to protect the receiving environment from potential harmful effects from stormwater discharges by reducing the stormwater related contaminants.

The following Sections provide a broad overview of stormwater treatment devices and their potential applicability to Geraldine (Section 10.1), with additional details provided for individual treatment devices (Sections 11.1 - 11.6). Costs and recommended treatment options are considered in Sections 12.0 and 13.0 respectively.

10.1 Treatment Processes

Infiltration/filtration and settlement are the two main treatment processes that are currently used for treating stormwater so as to mitigate the effects of the quality of the water in the discharge. Biological or chemical treatment options were not currently considered appropriate to treat the stormwater, either owing to fiscal concerns or because current understanding of the impacts of the effects of stormwater discharges from residential areas were not significantly great to deem them necessary.

Settlement treatment processes provide limited removal of soluble heavy metal and microbial contaminants. These contaminants are best removed by filtration processes. A number of international studies have shown that microbial communities in the upper 100 mm depths of soils provides effective removal of most soluble metals and microbial contaminants, so infiltration based treatment is highly desirable if removal of soluble heavy metal or microbial contaminants are required.

Treatment options can also be broken into 'natural' or 'proprietary' systems. Natural systems such as wetlands, infiltration basins and swales can be land intensive to construct, but are generally considered to have lower maintenance costs. Proprietary systems are often designed to operate with a low footprint, but can be expensive to install when treating larger flows and have an ongoing maintenance cost associated with them.

It should be noted that no common stormwater treatment devices provide effective treatment for microbial contaminants (*E. coli*) to meet the public health requirements for drinking water.

10.2 Stormwater Treatment Requirements

(PDP, 2013) provides typical values of contaminants in urban stormwater catchments in the Canterbury area make a recommendation for contaminant concentrations as shown in Table 12 below.

Table 12: Summary of typical stormwater quality characteristics from a residential area

Stormwater Parameter	Typical Concentration	NZDWS[1]	ANZECC 95 % guideline	LWRP Schedule 5	% Removal required to meet ANZECC 2000 (95% Threshold)
Suspended Solids	<200	-	-		
Hydrocarbons (mg/L)					
TPH	5	-	-		
Total PAH	0.007	-	0.0016 (Napthalene)	0.0016 (Napthalene)	n/a
BTEX	<0.003	**0.01** (Benzene), **0.8** (Toluene), **0.3** (Ethylene), **0.6** (Xylene)	0.95 (Benzene)	0.95 (Benzene)	n/a
Toxic Organics	<0.004	-	-		
Nutrients (mg/L)					
Nitrate Nitrogen	2.0	**11.3**	0.7		65%
Kejldalh Nitrogen	2.0	-	-		
Ammonia Nitrogen	0.6	1.5	0.9	2	0%
Total Nitrogen	4	-	0.614		85%
Dissolved Reactive Phosphorus	<0.1	-	0.01	0.006	90%
Total Phosphorus	0.4	-	0.033		92%
Total Metals (mg/L)					
Zinc	0.1 – 0.8	1.5	0.008	0.008	92-99%
Copper	0.02	**2**	0.0014	0.0014	93%
Lead	0.01	**0.01**	0.0034	0.0034	66%
Bacterial contaminants (cfu / 100 ml)					
Faecal coliforms	8,000	**< 1**	-		
E.coli	230	**< 1**	-	550	

Notes:

1: Values in bold represent Maximum Acceptable Values (MAV), other values represent Guideline Values (GV)

This shows that the key stormwater parameters of concern for groundwater supply in relation to the DWSNZ (2008) are bacterial contaminants (as indicated by *E. coli*), with all other parameters posing no real risk to a breach of the DWSNZ (2008). However for groundwater fed surface waterways the ANZECC (2000) guidelines are more applicable. These indicate that the parameters of concern are:

- Polyaromatic hydrocarbons (PAH);
- Nutrients (nitrate, ammonia, total nitrogen, dissolved reactive phosphorus and total phosphorus); and
- Metals (copper, lead and zinc).

10.3 Recommended Target Treatment Standards

10.3.1 Water quality

The following target treatment standards are recommended for new development and stormwater upgrades for Geraldine.

Table 13: Recommended Target Treatment Standards for Geraldine[1]

Suspended Solids	> 75%
Total zinc[2]	> 50%
Total copper[2]	> 50 %
Total Petroleum Hydrocarbons	> 50 %
E.coli	> 50 %

Notes:
1. *To be determined on accepted established empirical studies*
2. *Selection of device to consider likely dissolved metal proportion.*

10.3.2 Water Quantity Volume

It is not practical or economically acceptable to provide treatment of 100% of storm water runoff.

Review of stormwater treatment devices shows that there are limitations in reliably achieving 80% removal of contaminants from most forms of stormwater treatment devices and a treatment of a high proportion of rainfall runoff is required to achieve a best practical stormwater treatment option.

Typically this is achieved with stormwater treatment design requirements provide for treatment of between 85-95% of total rainfall volume from runoff from hardstanding surfaces. The design may be based on flow rate (or rainfall intensity) or flow volume (rainfall depth). These requirements typically require the treatment devices to provide for rainfall intensities of approximately 5-6 mm/hr or within the ranges of 15-25 mm of rainfall. The design requirements are dependent on local rainfall characteristics.

Treatment design by volume involves setting a set depth (mm of rainfall, or volume in m^3) of rainfall to provide treatment for, while disposing the runoff in excess of this to waterway/ground without treatment during large events. This set depth is defined to ensure a sufficient portion of the runoff is treated. Infiltration basins and detention ponds are typically designed in this manner. Systems based upon volume design/treatment tend to be space intensive (require detention areas) and as a result, are not ideal in existing developed areas. ARC Technical Publication No 10 (TP10) has now been superseded, but current practice in Auckland is to design stormwater treatment for 25 mm of rainfall; this is understood to provide for treatment of 95 % of rainfall (ARC, 2003). Analysis of Christchurch rainfall records at the Airport and the Gardens show that treatment of the first 25mm of rainfall from runoff from hard standing surfaces accounts for 78% of all rainfall (CCC Waterways, Wetlands Drainage Guide)

Similar analysis has been completed for Selwyn District Council for Rolleston and Darfield. This shows that the first 25 mm of runoff accounts for between 85% and 94% of the total rainfall volume (PDP, 2010).

Treatment design by flow rate is required for 'run-of-pipe' treatment systems. This approach involves setting a particular rainfall/flow rate that the system would be able to treat. Flows in excess of this would bypass the treatment system. Settling ponds and proprietary filter systems are designed in this manner. Flow based systems tend to escalate in cost rapidly as flow rates for treatment increase.

For both flow and volume based stormwater treatment systems, it is important therefore to strike a balance between treating a large enough flow rate to meet water quality objectives and recognising situations where bypassing large flows in infrequent storms is acceptable.

As such no specific rainfall analysis has been completed for Geraldine to size treatment systems. An interim standard of 25 mm rainfall depth or an intensity of 6 mm/hr is suggested in the interim until specific rainfall statistical analysis is completed for Geraldine. This needs to be refined with an analysis of rainfall records to determine the proportion of rainfall runoff that will be treated with this size of treatment device.

11.0 Treatment Options Considered

A range of commonly used stormwater treatment devices were considered for their applicability to the Serpentine and Waihi catchments. Typical treatment devices and removal efficiencies are summarised below in Table 14. Key advantages, disadvantages and suitability of selected devices are summarised in Table 15.

Table 14: Stormwater Treatment System Typical Removal Efficiencies

System	Pollutant Removal Efficiency (%)					
	TSS	Phosphorus	Nitrogen	BOD	Trace Metals	Bacteria
Grassed Swale[2]	20-60	20-40	20-40	20-40	20-60	20-40
Infiltration / Treatment Swale	60-100	40-80	40-80	20-60	40-100	60-100
Soakage Basin[2]	60-100	40-80	40-80	20-60	40-100	60-100
Dry Detention Basin[2]	40-80	40-60	20-40	20-40	20-60	0-40
Extended Detention Wet Pond[2]	60-80	40-80	40-60	20-60	40-80	40-80
Wetlands[2]	60-80	40-80	20-60	20-40	40-80	60-100
Proprietary Raingarden (Filterra®)[3]	85	70	34		55 total copper 56 total zinc	
Media Filter (Storm Filter®)[4]	80	54-74[5]	18-35[5]		41-54 total copper[5] 31-51 total zinc[5]	
Filter Strip[6]	20-60	20-40	20-40	20-40	20-60	20-40

Notes:

1. *Note: The level of pollutant removal will be subject to the level of provision of treatment system volume or surface areas relative to catchment runoff. As a general rule, the higher the concentration of in-flowing pollutants, the greater the degree of removal* (Christchurch City Council, 2003)
2. *Removal efficiencies as per Waterways, Wetlands and Drainage Guide for a conveyance swale* (Christchurch City Council, 2003).
3. *Median removal as per Contech (http://www.conteches.com/Products/Stormwater-Management/Biofiltration-Bioretention/Filterra, accessed 28/2/17) from various third party studies.*
4. *Stormwater Management StormFilter Performance Summary (Contech Stormwater Solutions).*
5. *95% confidence limits*
6. *Removal rates assumed to be similar to grassed swales*

Table 15: Treatment Device Matrix

Device	Advantage	Disadvantage	Potential applicability for Geraldine
Detention Basin	Existing detention basins in upper north-west catchment	• Large land footprint Limited removal of metals and nutrients	• Upper forest catchments (existing flood detention basins) • Reserves and parkland • Greenfield/new development Raukapuka and Geraldine Domains
Infiltration swale	• High treatment if properly designed	• Site constraints • Maintenance may be required with high influent TSS if infiltration capacity drops • Unsuitable for high water table or steep slopes	• Open/green spaces (parks) • Roadsides where land available • Greenfield development • Raukapuka and Geraldine Domains
Litter trap (in sump)	• Removal of gross pollutants • Useful for outfalls in high profile areas	• Ongoing maintenance required	• Sumps draining to parks and riverside
Oil interception	• Removal of oils and grease,	• Limited removal of other pollutants	• Roadside sump/outlets

Table 15: Treatment Device Matrix

Device	Advantage	Disadvantage	Potential applicability for Geraldine
(submerged outlet sump)	and gross pollutants • Retrofit existing roadside sumps/outlets		• Highly trafficked roads (Cox and Talbot Streets)
Proprietary media filter (e.g. Storm Filter)	• Small footprint • More cost-efficient for large catchments (> 2ha)	• Cost-inefficient for small developments • Ongoing maintenance costs	• Sumps, pipe outfalls to waterways • 2-10 ha catchments draining to Serpentine and Waihi River
Raingarden	• High treatment • Aesthetic values • At source control of discharge prior to entering pipe network	• Unsuitable for steep slopes • Cost • Maintenance may be required with high TSS if infiltration capacity drops • Space • Ongoing maintenance costs	• New developments
Raingarden - Proprietary (e.g. Filterra)[1]	• High treatment • Aesthetic values • At source control of discharge	• High capital cost • Ongoing maintenance costs	• On-site treatment, pipe outfalls to waterways • Existing development

Table 15: Treatment Device Matrix

Device	Advantage	Disadvantage	Potential applicability for Geraldine
	prior to entering pipe network		Talbot/Cox St upgrades
Riparian buffer/vegetated filter	Aesthetic values Low maintenance High levels of contaminant removal when designed effectively	Difficulty in providing full design retention time	Waihi floodway outlets
Soakaway infiltration device	Removal of metals from waterways	Potential discharge of bacteria to groundwater Build-up of contaminants in soil	Raukapuka outlet South Geraldine Note: subject to confirmation of soakage and groundwater levels
Wetland	Treats and temporarily detains stormwater Amenity values and creation of aquatic habitat Suitable where water table is high	Large land area Maintenance Contouring of existing landscape Downstream thermal impact for sensitive downstream waterways	End of Serpentine catchment

11.1 Stormwater Treatment Swales

Swales are widely used as collection channels in road carriage way formations in New Zealand and it is a popular misconception that such channels provide effective removal of contaminants from the stormwater discharges. While some of the design and construction requirements are transferable to use of swales for stormwater treatment purposes, the use of the swales for stormwater treatment does require additional considerations to those employed for swales as drainage collection channels.

Common design issues and limitations of stormwater swales include:

- Re-suspension of sediment;
- Design grass height 100 mm – 150 mm & maximum water treatment depth no greater than 100 mm above vegetation depth;
- Limited retentions times (treatment swales should have a minimum design retention time is 9 minutes to the outlet and avoidance of short circuiting of flows to ensure full treatment of stormwater flows.

The use of infiltration swales can provide effective removal of heavy metal contaminants including soluble metals. Where infiltration rates permit full disposal of the first flush stormwater to ground, well designed infiltration swales will remove over 90% of the stormwater contaminants from the stormwater discharged to the receiving waterway.

11.2 Detention Basin

Detention basins are constructed depression that temporarily store water to attenuate flood flows, and also provide treatment by allowing suspended solids (TSS) to settle out, along with contaminants bound to sediments (e.g. particulate forms of heavy metals). Detention basins can be dry, whereby they remain dry between rainfall events, or wet, where the basin retains a wetted area between events. Dry detention basins are most effective at removing coarse sediments. Existing detention basins are located in the north-west of the Serpentine catchment (Jollie and Peel Detention Basins).

As with swales, infiltration basins will provide removal of higher levels of stormwater contaminants including dissolved metals from the receiving environment.

11.3 Riparian Buffer

Maintaining a healthy riparian buffer (vegetated strips) is important in areas where stormwater is discharged from an outlet into or near receiving waterways. A healthy vegetation buffer will help distribute and slow down the water discharged from an outlet (a concentrated point source discharge), and thereby reduce the potential for erosion. By slowing the flow additional treatment may be achieved by allowing suspending sediments to settle out.

11.4 Media Filters

Media filters (e.g. Storm Filters) are compact stormwater media filtration systems that are able to remove a variety of contaminants. Devices such as Storm Filters can remove more than 75% TSS (ARC, 2003), as well as 30-60% total zinc and total copper. Media filters can also remove gross pollutants and provide treatment for hydrocarbons. Appropriately selected and installed media filters can achieve high levels of removal of both dissolved and un-dissolved heavy metals, suspended solids and hydrocarbons. A copy of the product sheet is included in Appendix C.

11.5 Raingardens

Raingardens (or bio-retention systems) are planted areas that filter stormwater through a vegetated soil media layer, and thereafter water is generally collected through perforated pipes at the base of the raingarden to direct treated water to an outlet. Raingardens offer treatment via ponding of water within the planted raingarden area, which subsequently is filtered through the vegetation and underlying soils and plant roots, which absorbs and filters stormwater before discharging into the stormwater network or surface/ground-water. Raingardens are suitable for retrofitting into existing developed areas, where space requirements permit.

Proprietary systems are available, such as the “Filterra” treatment device supplied by Stormwater360, which offers the advantage of having a much smaller footprint than traditional raingardens. A copy of the product sheet, which includes expected pollutant removal rates, is included in Appendix C.

11.6 Constructed Wetlands

Wetlands detain flows to allow sediment to settle and also remove contaminants by adhesion to vegetation and decomposition. Constructed wetlands can be used for stormwater treatment to remove dissolved contaminants and fine particles, and also provide filtration and denitrification. In addition to providing stormwater treatment, constructed wetlands have the added benefit of providing landscape and ecological values. Wetlands are suitable for end of catchment treatment and therefore can treat larger areas, however they also require a larger land footprint to do so and therefore may not be suitable for built up areas.

12.0 Cost Comparison

12.1 Capital Costs

Graph 1 below shows a comparison of capital costs for various treatment devices. Infiltration basins present the lowest capital cost. The next lowest capital costs is dependent upon catchment size; for catchments < 2ha, grassed treatment swales are less expensive than media filters (e.g. Storm Filters), whereas for catchments > 2ha media filters become more cost-efficient. The graph also indicates that proprietary raingardens (e.g. Filterra) present the highest capital cost.

12.2 Land Requirements

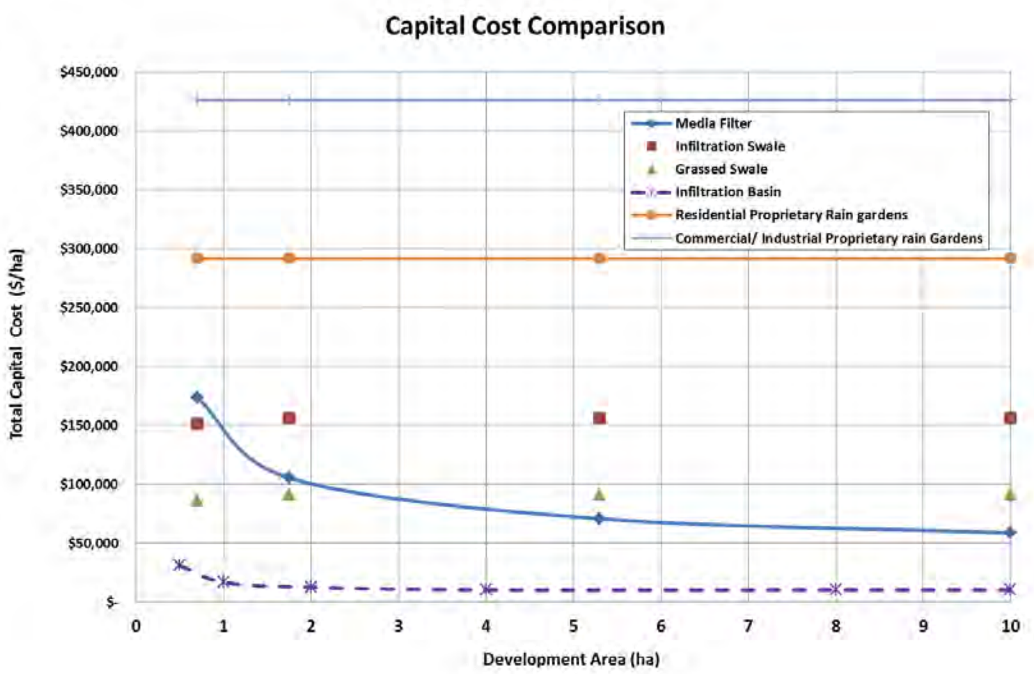
As shown in Graph 2, the area of land required to install proprietary raingarden treatment devices (e.g. Filterra) is considerably less than other treatment options for development areas less than 5 ha. For areas larger than 5 ha, the required land area for media filtration devices becomes slightly smaller than that required proprietary raingardens.

12.3 Maintenance Costs

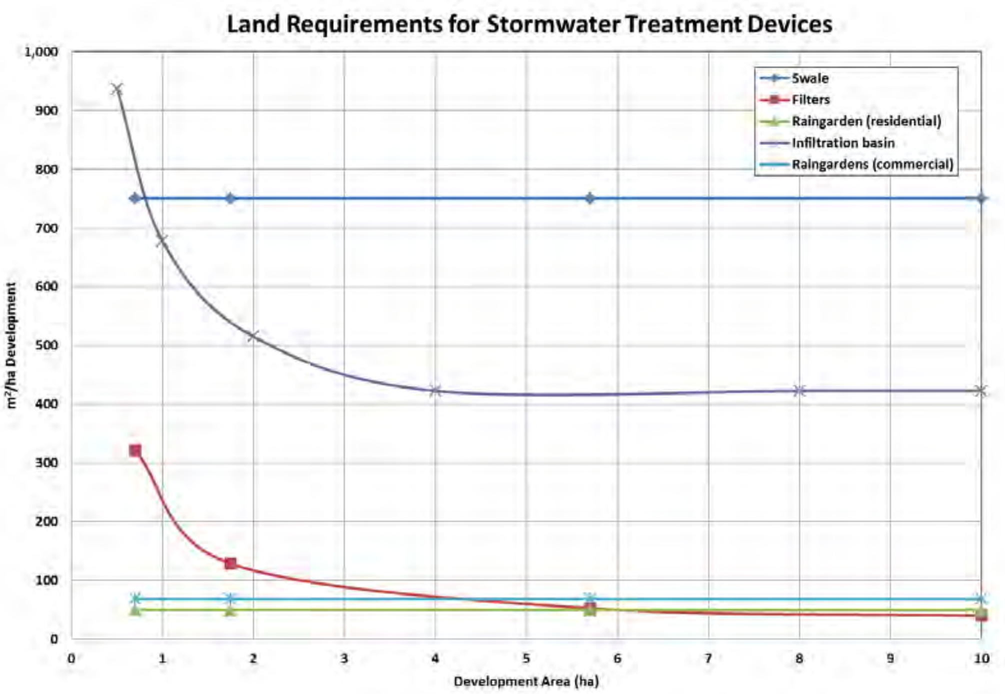
Graph 3 shows that the ongoing maintenance costs for various treatment devices. For catchments smaller than 1 ha, swales and infiltration basins have the lowest maintenance costs. For development areas larger than 2 ha, media filters start to become more cost effective with respect to maintenance costs, although still present a higher cost than swales and infiltration basins. Raingardens generally have the highest associated maintenance costs.

12.4 Total Net Present Value (NPV) Lifecycle Costs

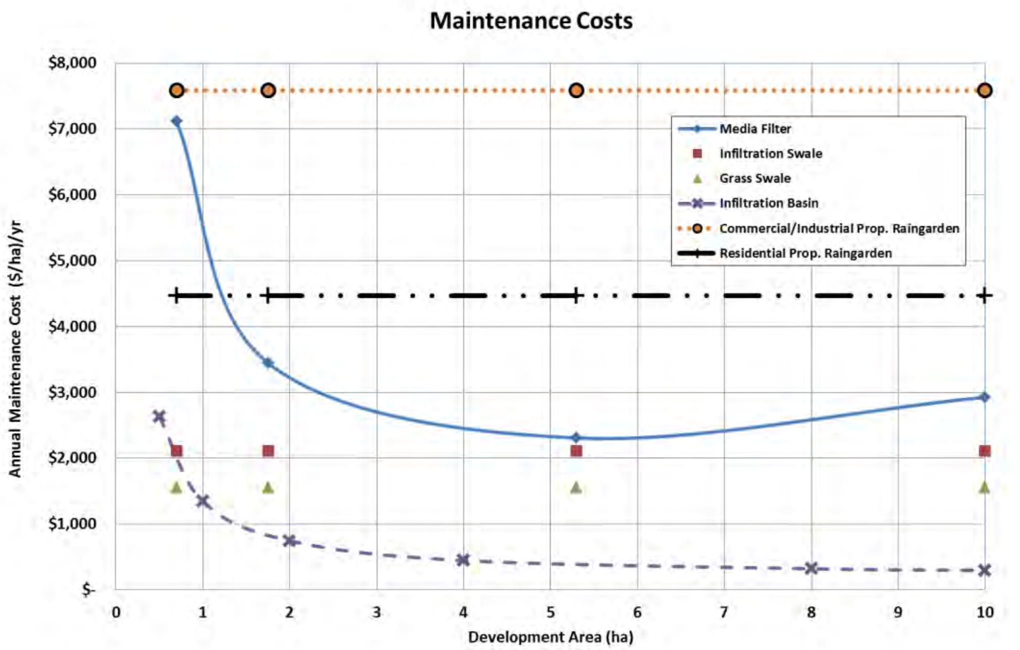
The NPV of the total lifecycle costs for the various options are shown on Graph 4. As indicated in Graph 4, the total life cycle costs are cheapest for infiltration basins, and media filters (e.g. Storm Filters) become more cost effective for development areas larger than 2 ha. Raingardens present the highest lifecycle cost.



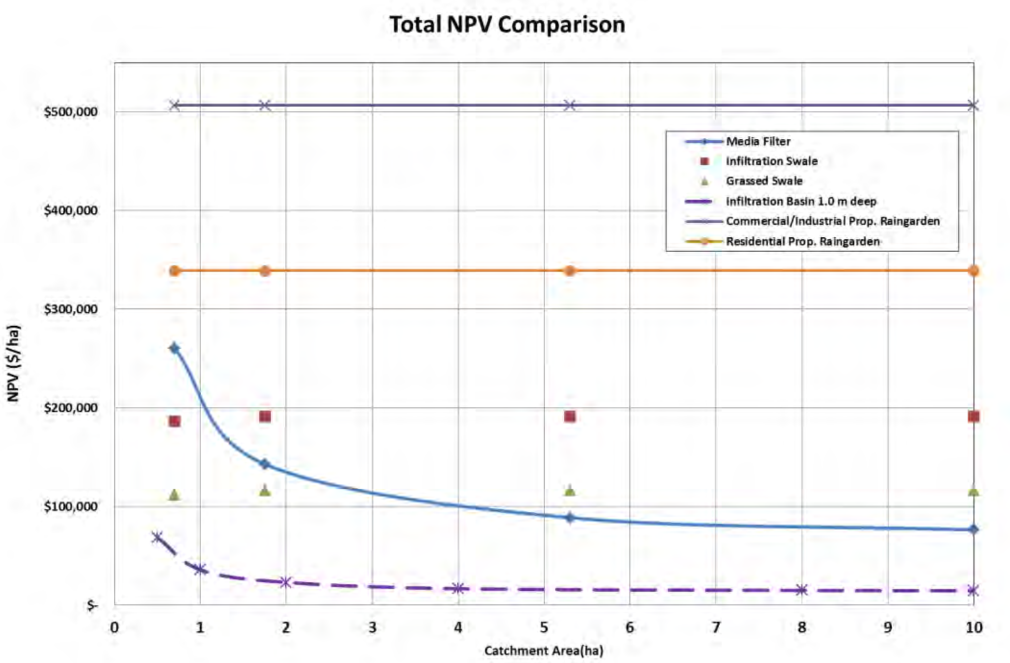
Graph 1: Capital Cost Comparison.



Graph 2: Land area requirements comparison.



Graph 3: Average annual maintenance costs for the stormwater treatment devices over a 100 year lifespan.



Graph 4: Total Net Present Value Life Cycle Costs comparison of the different treatment devices. (100 year life, 7% discount rate)

13.0 Effective Treatment Options for Geraldine

Based on the above review, a range of treatment devices were identified to potentially be suitable for Geraldine and are listed below in Sections 13.1-13.5. Treatment scenarios are discussed in Section 14.0.

Given that limited growth in expected in Geraldine, and the need for treatment devices that can be installed within already developed areas (i.e. space constraints), devices were generally selected that can be retrofitted in existing developments.

13.1 Media Filters and Proprietary Raingardens

Media filters (e.g. Storm Filters) and proprietary raingardens (e.g. Filterra) have been considered for retrofitting existing development areas in Geraldine for the treatment of urban runoff (TSS and heavy metals). As noted in Section 12.0, proprietary raingardens are generally more expensive than media filters, with the exception of small catchments. For small development areas, proprietary raingardens are more cost effective, and require less land area to install. In addition, raingarden systems provide amenity value.

13.2 Oil Interceptors (Submerged Outlets) and Litter Traps

The CLM results indicate that the TPH loads are highest alongside the highest trafficked roads, such as Talbot Street and Cox Street (SH79), as shown in Figure 8. Approximately 77% of the TPH load is derived from such roads, which are shown as ‘Road 1k – 5k’ in Figure 3, Appendix A. Therefore, to have the greatest effect on TPH removal, treatment should at a minimum target these areas. In addition to providing TPH treatment, oil interceptors (submerged outlets) will also help remove floatable solids. Litter traps are also recommended for sumps draining to waterways and parks located in these areas

13.3 Riparian Planting and filter strips

Where stormwater pipes discharge into/in close proximity to the Waihi, it is important to maintain healthy riparian vegetation/vegetation buffer to offer further treatment of stormwater prior to discharging into the waterways. In addition, a sufficient and healthy riparian buffer will improve the distribution and decrease the velocity of stormwater discharged from pipe outlets, and will thereby help lessen the impact of these point source discharges and reduce the potential for bank erosion.

13.4 Constructed Wetland

A constructed wetland may be a suitable treatment solution for the Serpentine catchment, providing end-of-catchment treatment of urban runoff for TSS and heavy metals. Furthermore, wetlands provide additional benefits such as amenity and ecological values. Notwithstanding, a wetland at this location would only serve to provide protection to the Waihi River, which to date has been shown to have limited adverse effects from the stormwater in Serpentine Creek.

Preliminary sizing calculations were undertaken in accordance with Christchurch City Council Waterways, Wetlands and Drainage Guide (2003) to size a wetland at the end of the Serpentine catchment. Preliminary sizing indicates that a constructed wetland would require a total land area of approximately 12 ha.

Figure 10, Appendix A, indicates the potential size and location of a constructed wetland. The wetland concept (Figure 10) includes two parallel wetlands of approximately 590 m length. The preliminary design, which includes a 20 m buffer around the perimeter of the wetlands to allow for wetland side slopes as well as easy access for maintenance, has an overall land area of approximately 19.7 ha of land. Preliminary sizing calculations indicate that the wetlands would be able to treat the first 25 mm of runoff for the upstream Serpentine catchment.

The required land area may be able to be refined with the exclusion of the upstream rural catchments via throttling of the detention dams. However, an allowance must also be made for the provision of pre-treatment forebays prior to the wetlands.

13.5 Detention Basins

The CLM results indicate that the highest proportion of TSS loading comes from the upper catchments, where the land use is predominantly forest and pasture. The CLM modelling indicate that contributing Catchments 165 and 16, which drain to the Jollie and Peel Detention Basins respectively, generate 51% and 21% of the total Serpentine catchment TSS load.

As noted earlier in Table 14, an appropriately designed and well maintained detention basin is expected to remove 40-80% TSS. Assuming a 60% TSS removal rate, and the calculated contaminant loads, this would equate to potentially a combined TSS removal of 73 tonnes (or 120 m^3) TSS per year from the Jollie and Peel Detention Basins. Therefore, these areas should be targeted for TSS removal and the basins should be inspected regularly to verify they are performing satisfactorily. It is noted both the Jollie and Peel Detention Basins include significant areas of forested vegetation in their immediate vicinity. In the first instance, it is recommended that the vegetated buffers should be retained and enhanced and sediment discharges verified prior to any extensive modifications to these detention structures. Ensuring a healthy vegetation buffer is present will assist with TSS removal at these locations.
In addition, Groves (2016) identified the potential to further attenuate these detention basins without causing undue flooding downstream. Therefore, this provides TDC the opportunity to utilise these assets as water quality improvements to the downstream catchment.

14.0 Treatment Strategies

Three treatment strategies were considered further which are listed below. A summary of each treatment strategy, including capital costs, is presented as Table 16 on the following pages. The capital costs are preliminary estimates (± 30 %) and include a 10% allowance for preliminary and general and 25% contingency.

- Strategy 1 (Figure 11):
  - Oil interceptors for highly trafficked roads;
  - Enhanced outlets on flood detention dams
  - Media filters (e.g. Storm Filter); and
  - Enhanced riparian planting for Waihi outlets.
- Strategy 2 (Figure 12):
  - Oil interceptors for highly trafficked roads;
  - Enhanced outlets on flood detention dams
  - Proprietary raingardens (e.g. Filterra) in Geraldine town centre;
  - Media filters (e.g. Storm Filter); and
  - Enhanced riparian planting for Waihi outlets.
- Strategy 3 (Figure 13):
  - Oil interceptors for highly trafficked roads;
  - Enhanced outlets on flood detention dams
  - Media filters (e.g. Storm Filter) for Waihi sub-catchments;
  - Enhanced riparian planting for Waihi outlets; and
  - Constructed wetland for Serpentine catchment.

Table 16: Treatment Device Options and Capital Costs

Strategy	Device/Option	Cost (± 30 %)	Treated Area[1]
Strategy 1	Oil interception (submerged outlets)[2]	$112,500	
	Media filters (e.g. Storm Filters)[3]	$9,474,000	
	Enhanced riparian planting at pipe outlets to Waihi[4]	$70,000	
	Enhanced outlets on flood detention dams[5]	$40,000	
	Subtotal	**$9,696,500**	
	Design and Planning (10 %)	$969,500	
	Total	**$10,660,000**	114 ha (76%)
Strategy 2	Oil interception (submerged outlets)[2]	$112,500	
	Proprietary raingardens (e.g. Filterra) in town centre[3]	$1,934,000	
	Media filters (e.g. Storm Filters)[3]	$7,498,000	
	Enhanced riparian planting at pipe outlets to Waihi[4]	$70,000	
	Enhanced outlets on flood detention dams[5]	$40,000	
	Subtotal	**$9,654,500**	
	Design and Planning (10 %)	$965,500	
	Total	**$10,620,000**	104 ha (69%)

Table 16: Treatment Device Options and Capital Costs

Strategy	Device/Option	Cost (± 30 %)	Treated Area[1]
Strategy 3	Oil interception (submerged outlets)[2]	$112,500	
	Media filters (e.g. Storm Filters) at Waihi pipe outlets	$4,646,500	
	Enhance riparian planting at pipe outlets to Waihi[3]	$70,000	
	Constructed wetland for Serpentine catchment[6,]	$3,750,000	
	Enhanced outlets on flood detention dams[5]	$40,000	
	Subtotal	**$8,619,000**	
	Design and Planning (10 %)	$862,000	
	Total	**$9,481,000**	144 ha (96%)

Notes:

1. *Treated areas as shown in Figure 11 to Figure 13, excluding areas marked as 'infiltration area'. Percentages are given as % of urban area treated within the CLM modelled area (excluding infiltration areas).*
2. *Costs are for 45 sumps (Talbot Street, Cox Street and SH79)*
3. *Treatment areas as shown in Figure 11 (cost does not include areas marked "Potential Treatment Areas").*
4. *Costs for riparian planting at 7 Waihi outlets.*
5. *Costs for enhancement of two detention basins (Jollie and Peel Detention Basins)*
6. *Treatment area is the Serpentine catchment, excluding Catchment Areas 16, 155, 157 and 165 to the north-west, and the rural portion of Catchment Area 0 at the south of the Serpentine catchment, as shown in Figure 13.*
7. *Costs include a 10% allowance for preliminary and general and 25% contingency. PDP has no control over the cost of third party labour, materials, equipment or services furnished by others, or over contractors' methods of determining prices, or over competitive bidding or market conditions. Any opinion or estimate of costs by PDP is to be made on the basis of PDP's experience and qualifications and represents PDP's judgement as an experienced and qualified professional.*

14.1 Anticipated Contaminant Load Reductions

The expected reductions in contaminants loads of TSS, zinc and copper are summarised below in Table 17, which provides total contaminant load reductions in terms of mass (kg/yr) and as a percent of the total CLM modelled catchment loads. The results indicate that Strategy 3, which includes a constructed wetland towards the bottom of the Serpentine catchment, is anticipated to provide the greatest removal of contaminant loads out of the three strategies considered.

Table 17: Anticipated Reduction in Contaminant Load

Strategy	TSS Removal	Zinc Removal	Copper Removal
Strategy 1	140,020 kg/yr (72%)	27.5 kg/yr (37%)	2.0 kg/yr (32%)
Strategy 2	135,825 kg/yr (70%)	26.7 kg/yr (36%)	2.0 kg/yr (31%)
Strategy 3	145,018 kg/yr (75%)	36.8 kg/yr (50%)	2.9 kg/yr (45%)

Notes:

1. *Percentages are given as the fraction of the total CLM modelled catchment.*
2. *Note: the above contaminant load removal figures do not include removal by riparian buffers. To estimate removal via riparian buffers further investigations are required, on a case by case basis, including retention times within the buffers.*

15.0 Additional Considerations

15.1 Raukapuka Discharges

The potential exists to divert the Raukapuka outlet, located towards the east of the catchment and adjacent to McKenzie Street/Orari Station Road, into an infiltration basin to discharge stormwater runoff to ground,[5] rather than discharging to the Raukapuka as is currently occurring. Whilst infiltration could provide additional stormwater treatment, it is noted that infiltration basins provide limited treatment for microbial contaminants, and therefore this option could potentially affect groundwater quality. The risks of the microbial contaminants discharged to ground needs to be weighed up against the risks and impact of the discharges of sediment and heavy metal contaminants discharged to a waterway.

15.2 Waihi Outlets

As an alternative to enhanced riparian planting at Waihi pipe outlets, soak pits may be considered to discharge stormwater to ground at these locations.

As noted above, discharges to ground could potentially affect groundwater quality in terms of bacterial contamination. However, any surface water discharge to the Waihi will also be expected to have an interaction with the groundwater aquifer under the river channel.

[5] Subject to confirmation of soakage and groundwater levels.

16.0 Proposed Treatment Strategy

A CLM was developed for the Geraldine township and surrounding area to estimate contaminant loading for suspended sediment, hydrocarbons (TPH), zinc and copper. The CLM results indicate that more than half of the CLM modelled catchment TSS load originates from the north-western sub-catchments containing forested areas, and three quarters of TPH from the highest trafficked roads such as Cox Street and Talbot Street. Zinc and copper loads are generally expected to be highest in industrial and commercial sub-catchments.

It is recommended that TDC target these areas for cost effective prevention of stormwater contaminants from the receiving waterways.

As limited growth is anticipated in Geraldine, stormwater treatment options are likely to be restricted to compact end of pipe solutions such as media filters or making use of and enhancing the existing riparian buffers found in the Waihi River floodway between pipe outfalls and the low flow channel. Compact proprietary raingarden solutions are potentially applicable to provide enhanced amenity with at-source control in the main streets.

Where possible, infiltration devices are recommended to provide effective removal of heavy metal contaminants from the environment.

A range of stormwater treatment devices were considered for the Waihi and Serpentine catchments. A cost comparison was undertaken for a range of treatment devices, including media filters (Storm Filter) and proprietary raingardens (Filterra), which generally shows that the media filter is the cheaper option compared to proprietary raingardens. As the development area becomes increasingly small (< 0.5 ha), media filters become increasingly expensive and require a larger land footprint than proprietary raingardens. Based on the cost assessment, media filters and raingardens were considered to be most relevant to Geraldine given existing developments and the need to retrofit stormwater treatment devices. Ensuring healthy vegetation buffers at the two existing detention basins, and planting riparian buffers at Waihi pipe outlets, were also considered to be relevant, as well as oil interceptors (submerged outlets) along highly trafficked roads. Lastly, a constructed wetland was considered as an end of catchment treatment device for the Serpentine catchment.

Subsequently three treatment strategies were investigated, which included the use of media filters, proprietary raingardens, oil interceptors, riparian planting, and a constructed wetland. The wetland option (Strategy 3) was determined to be the most cost effective solution, and provide the greatest benefit in terms of reducing contaminant loads reaching the receiving waterways. The price estimate for this option is approximately $9.5 million (+/- 30%), and the anticipated removals in contaminant loads are 75% for TSS, 50% zinc and 45% copper, in terms of total loads for the modelled CLM catchment area. However, this option is dependent on the availability of private land. The benefits of treating flows from Serpentine Creek at this location may be limited, if it is confirmed that there is limited impact of the flows from Serpentine Creek on the water quality in the Waihi River downstream of their confluence.

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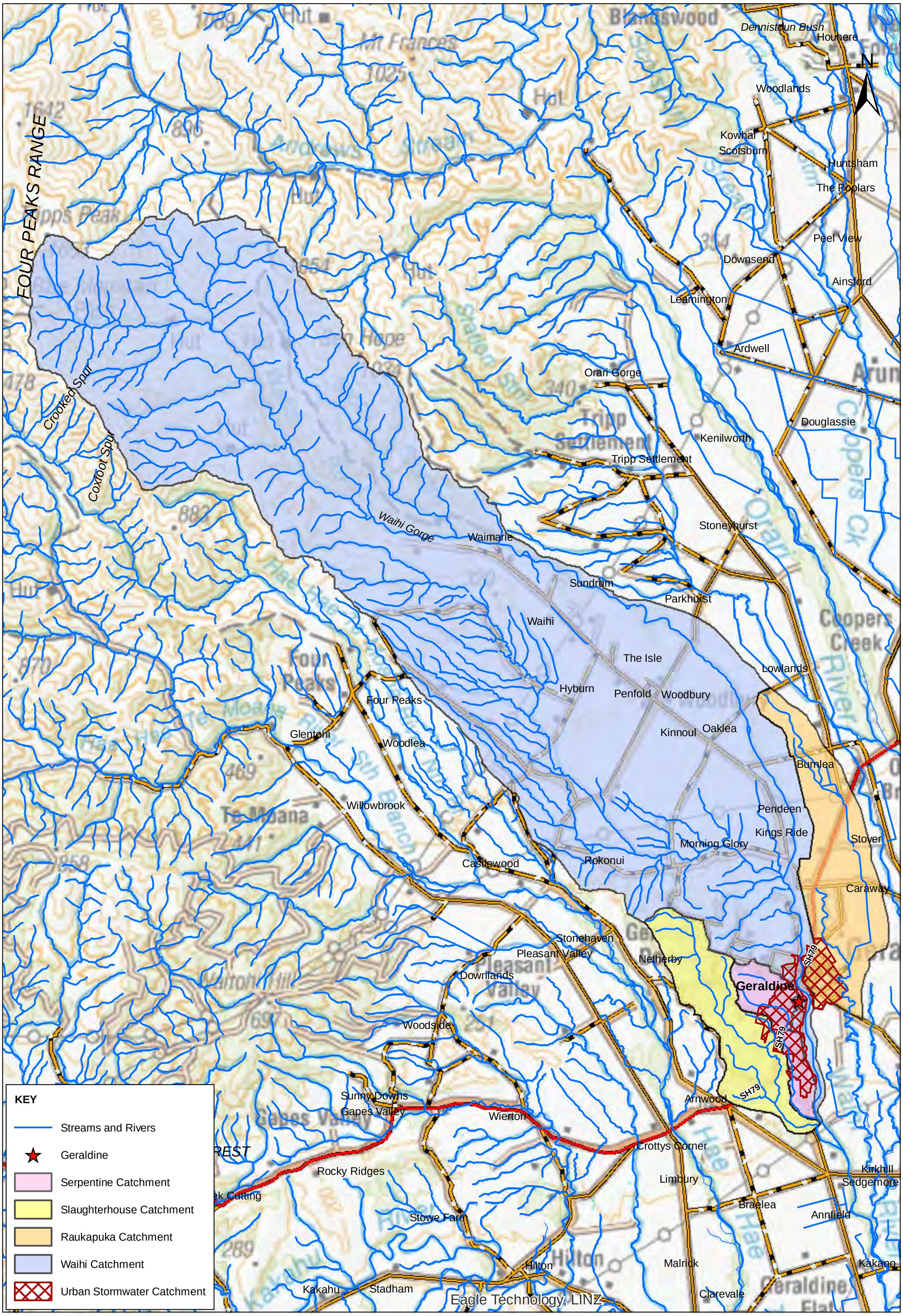
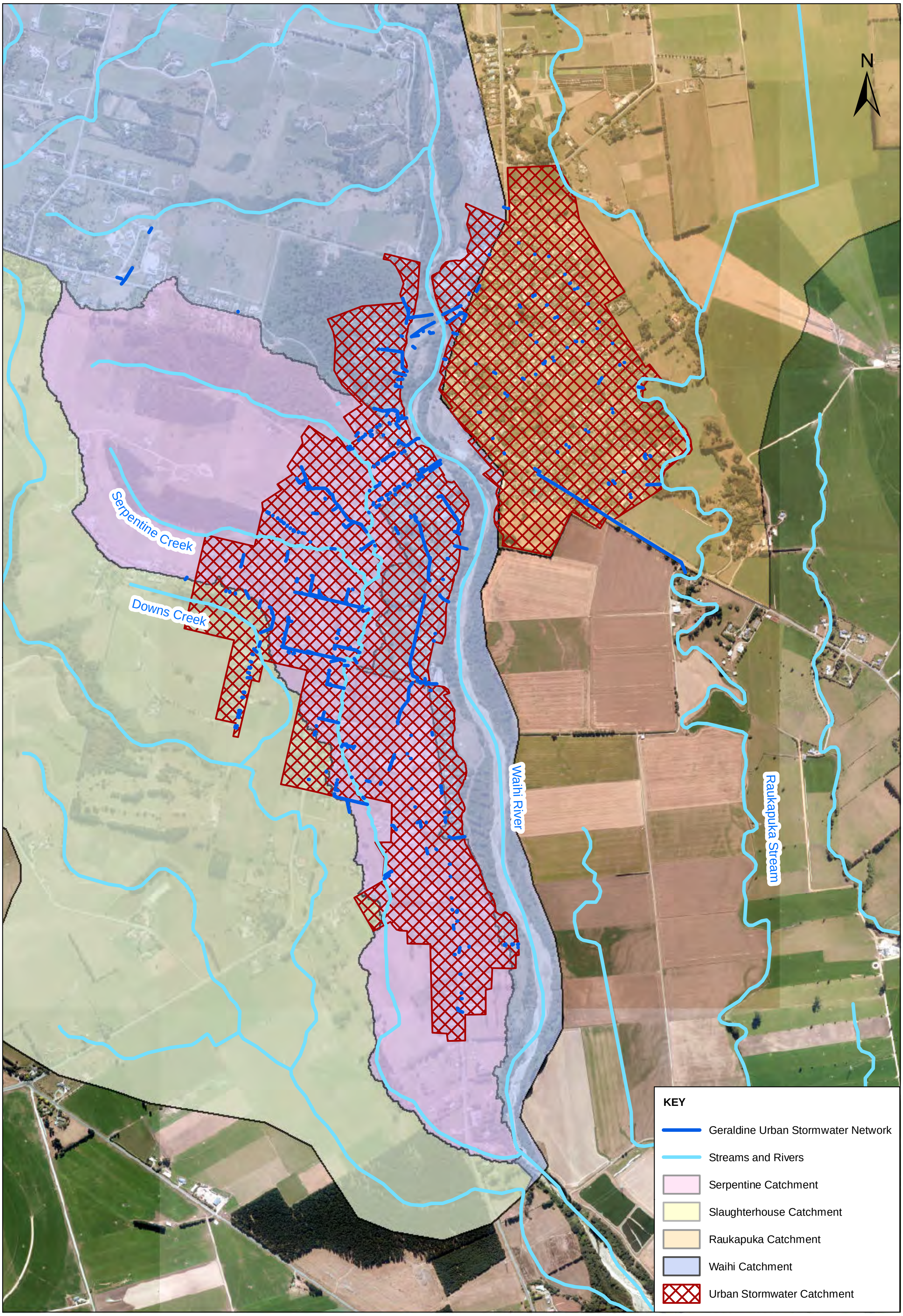


SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 1 : GERALDINE CATCHMENT AREAS

SCALE : 1:110,000 (A4)
0 500 1,000 2,000 3,000 4,000
METRES



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2. CADASTRAL INFORMATION DERIVED FROM LINZ DATA.

FIGURE 2
GERALDINE URBAN STORMWATER CATCHMENT

SCALE : 1:20,000 (A4)
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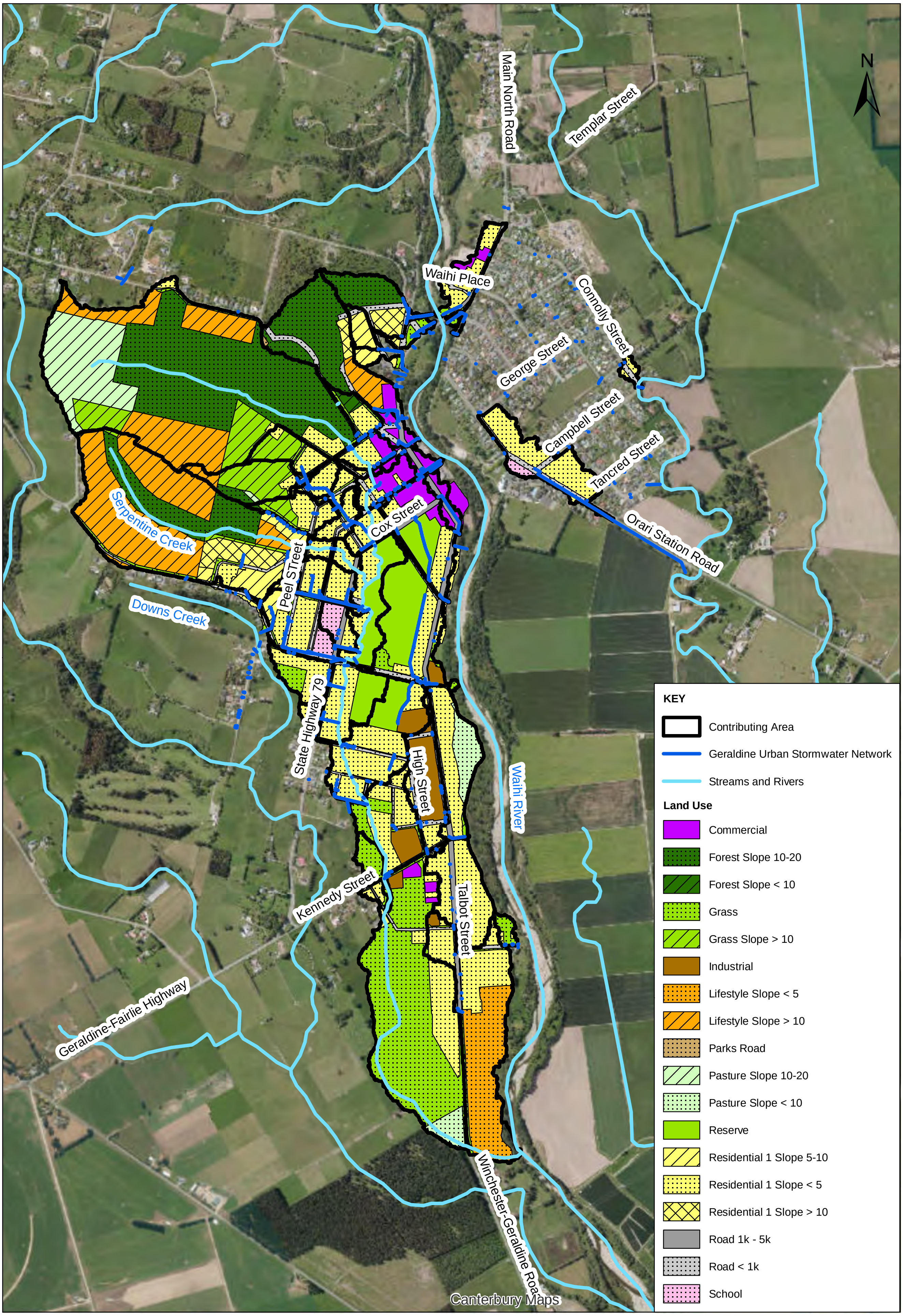
METRES



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2. CADASTRAL INFORMATION DERIVED FROM LINZ DATA.

FIGURE 3
CONTAMINANT LOAD MODEL - SURFACE AREAS

SCALE : 1:20,000 (A4)
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METRES

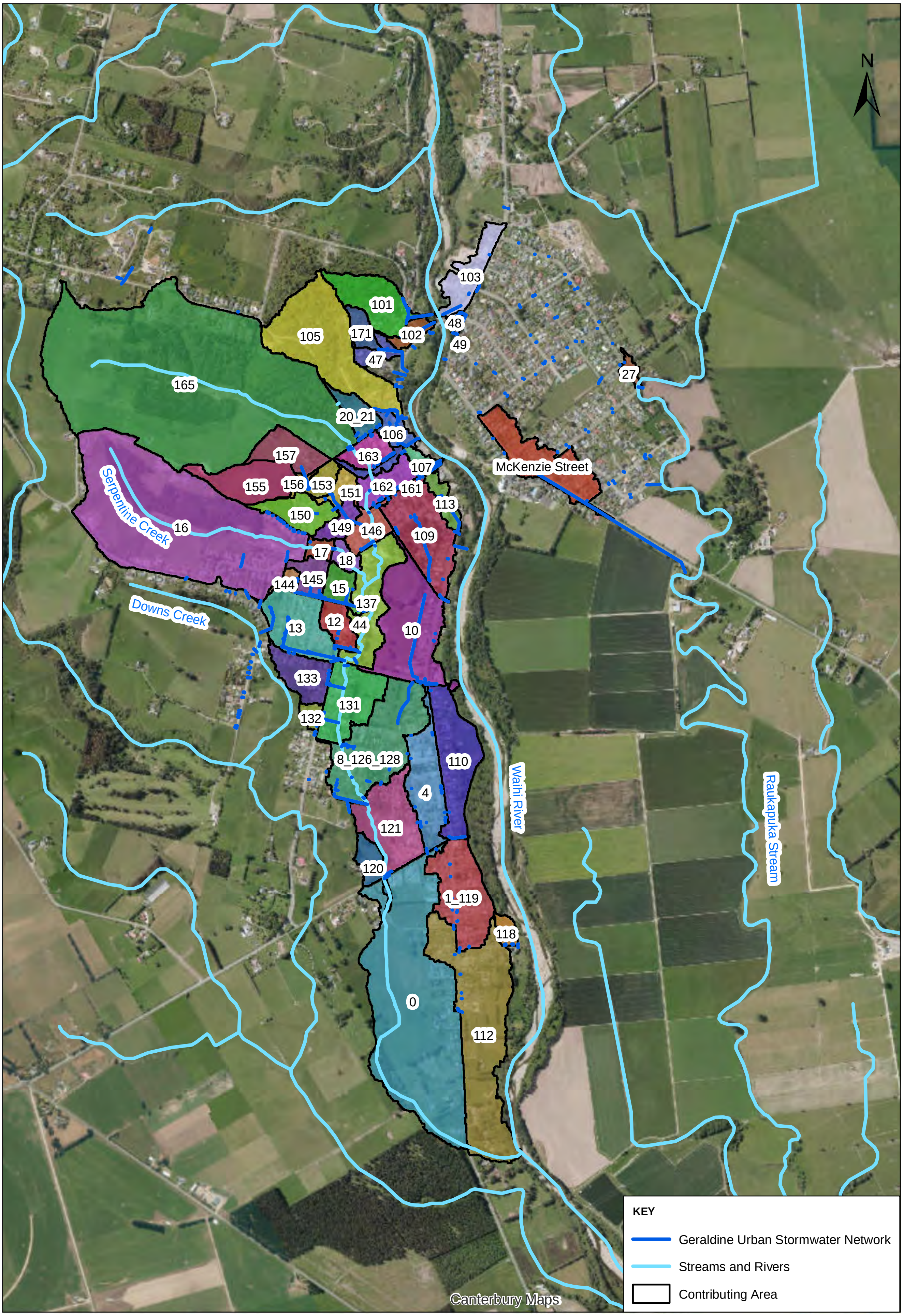

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FIGURE 4
CONTAMINANT LOAD MODEL CONTRIBUTING AREAS

SCALE : 1:20,000 (A4)
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METRES

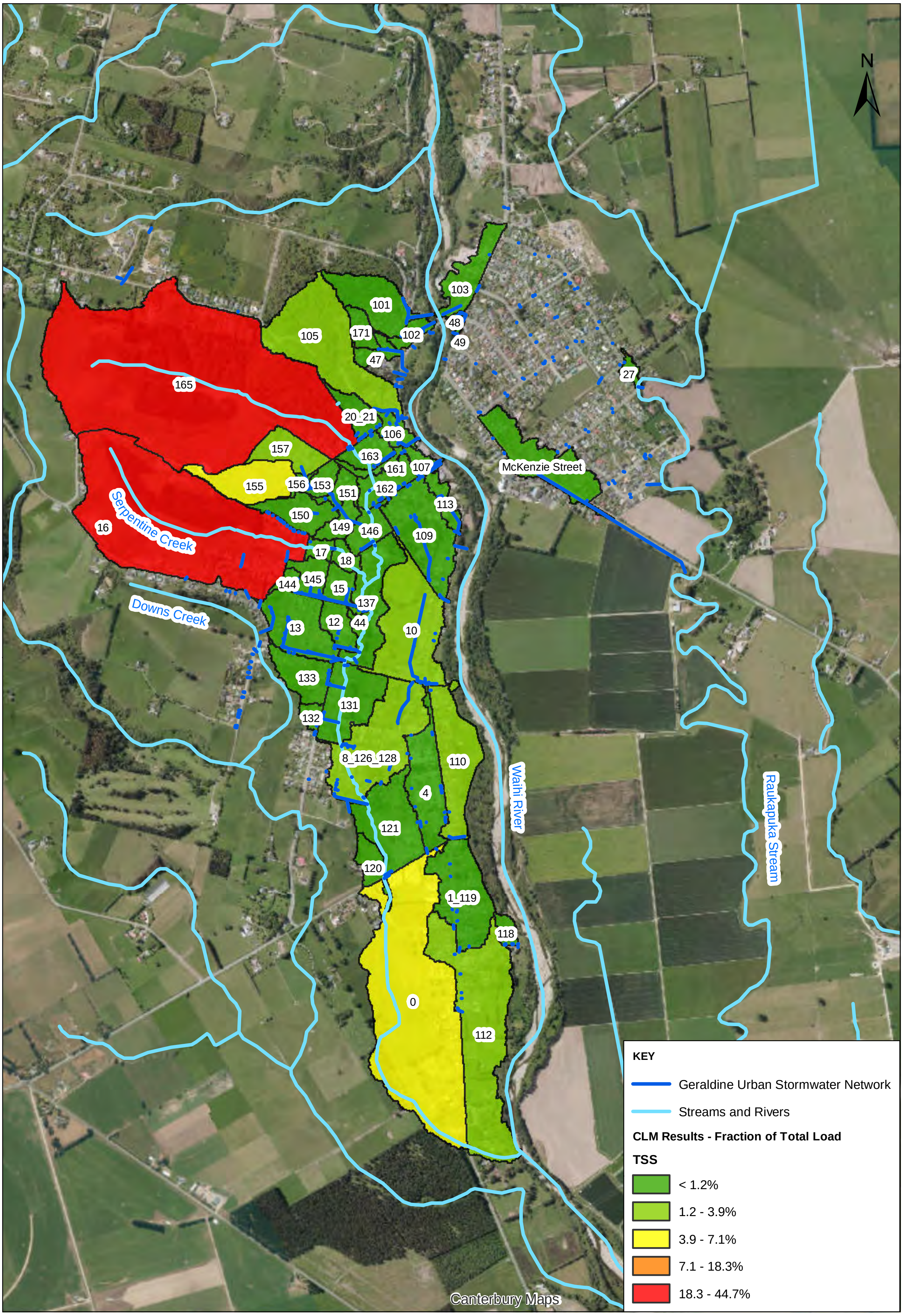

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FIGURE 5
CONTAMINANT LOAD MODEL - SOURCES OF TSS BY CATCHMENT

SCALE : 1:20,000 (A4)
0 100 200 400 600 800
METRES

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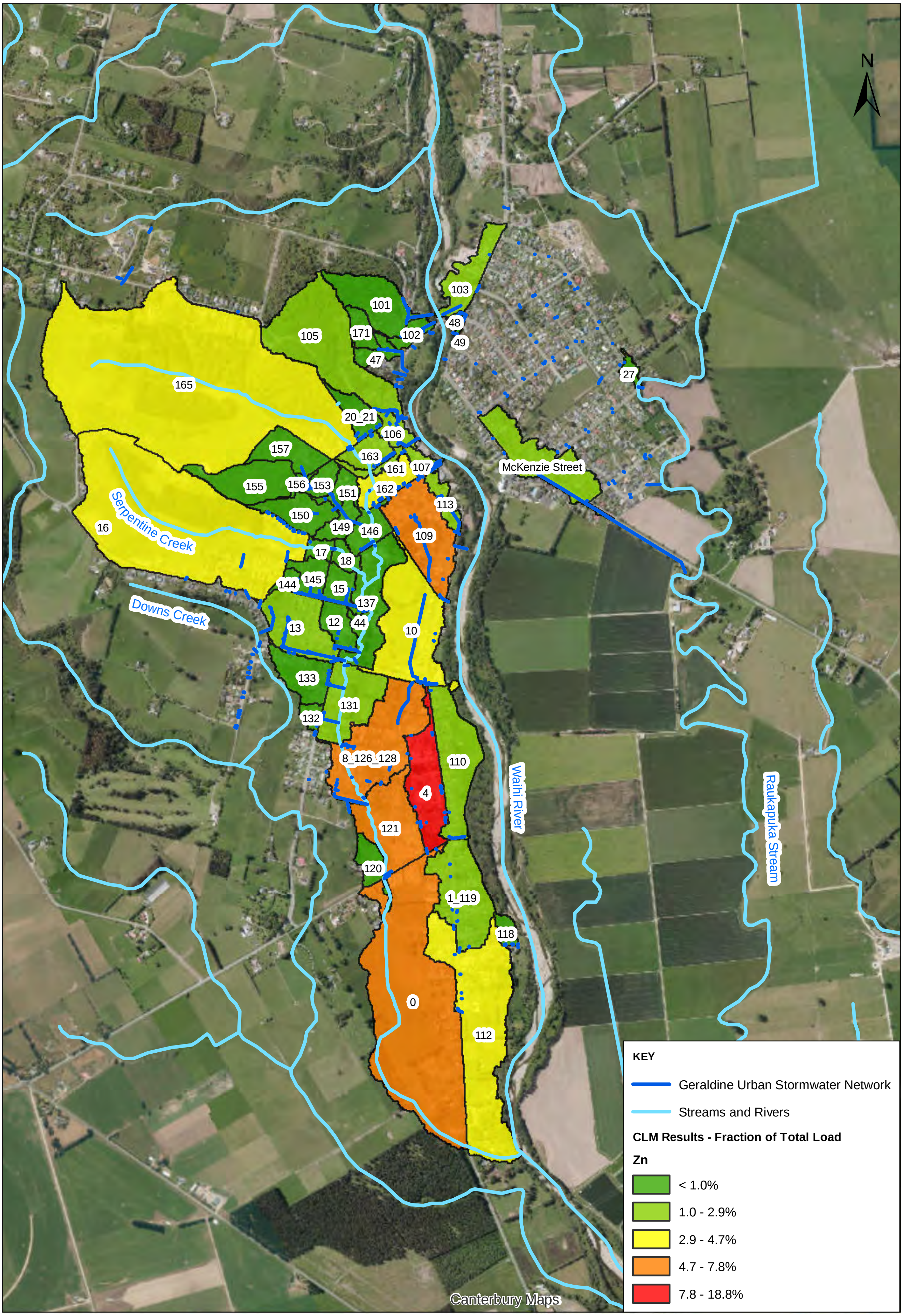

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FIGURE 6
CONTAMINANT LOAD MODEL -
SOURCES OF ZINC BY CATCHMENT

SCALE : 1:20,000 (A4)
0 100 200 400 600 800
METRES

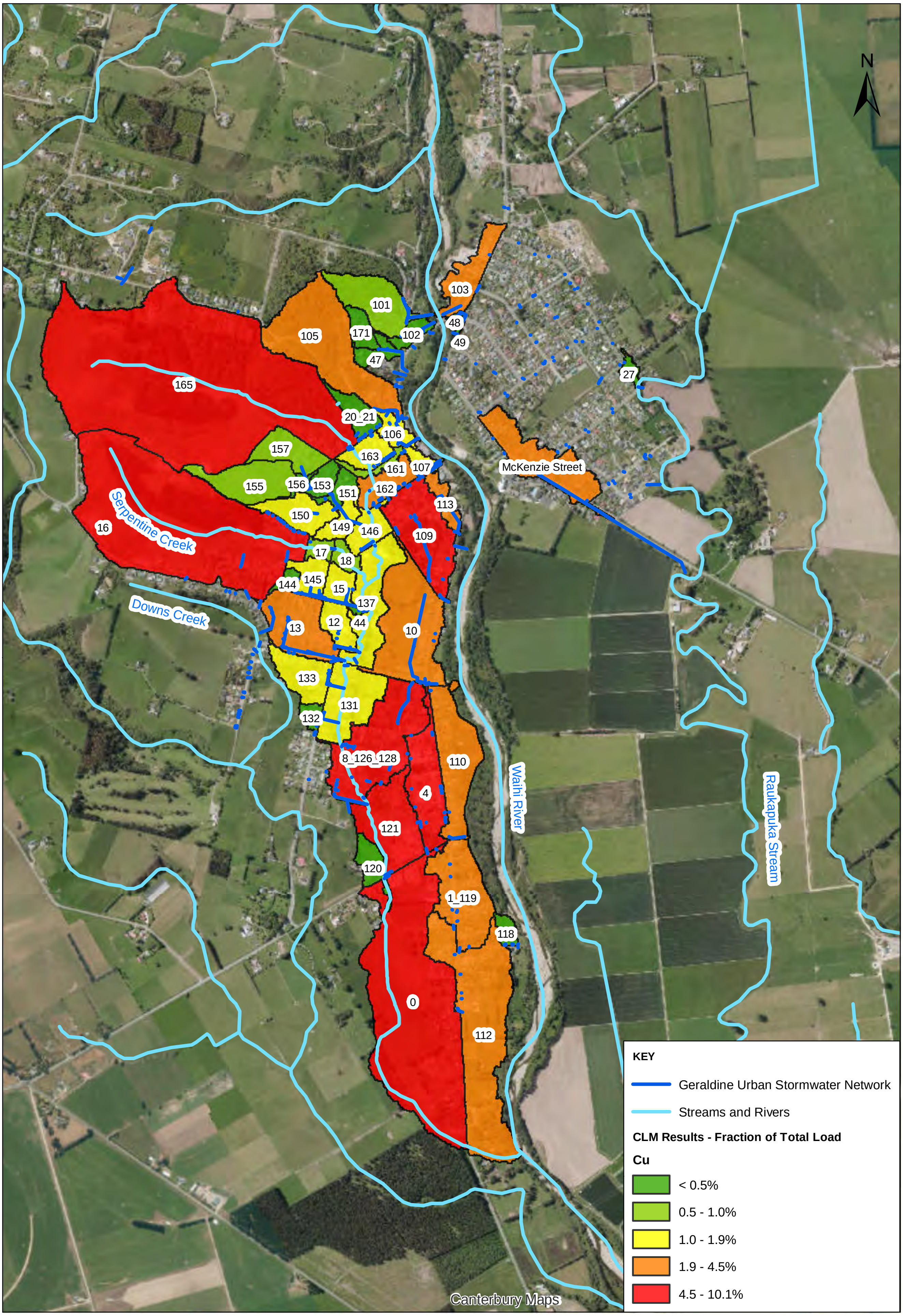

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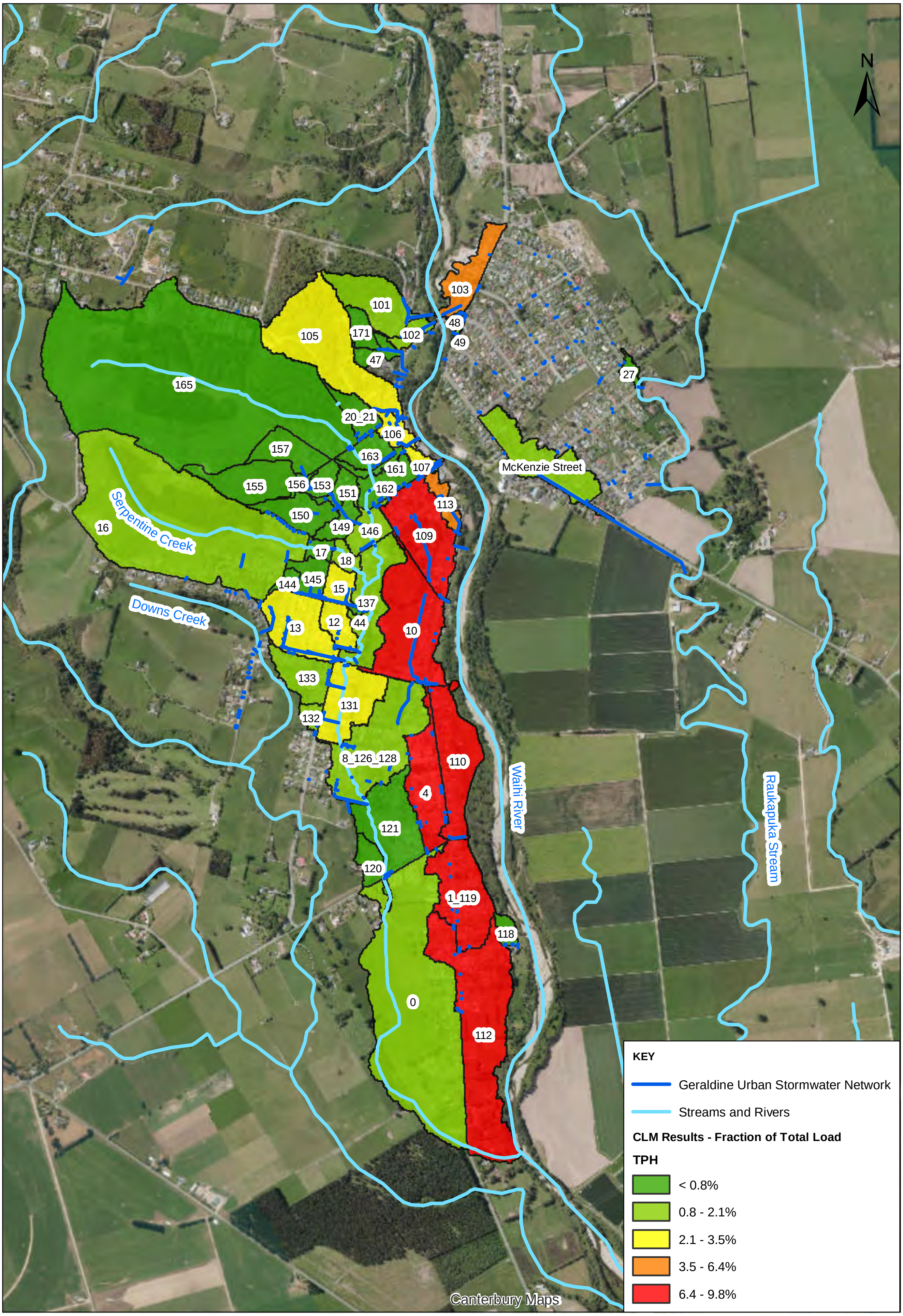
FIGURE 7
CONTAMINANT LOAD MODEL -
SOURCES OF COPPER BY CATCHMENT

SCALE : 1:20,000 (A4)
0 100 200 400 600 800
METRES

PATTLE DELAMORE PARTNERS LTD

C03489300_CLM_FIGURE7_CU_Results.mxd AUGUST 2017 ISSUE2



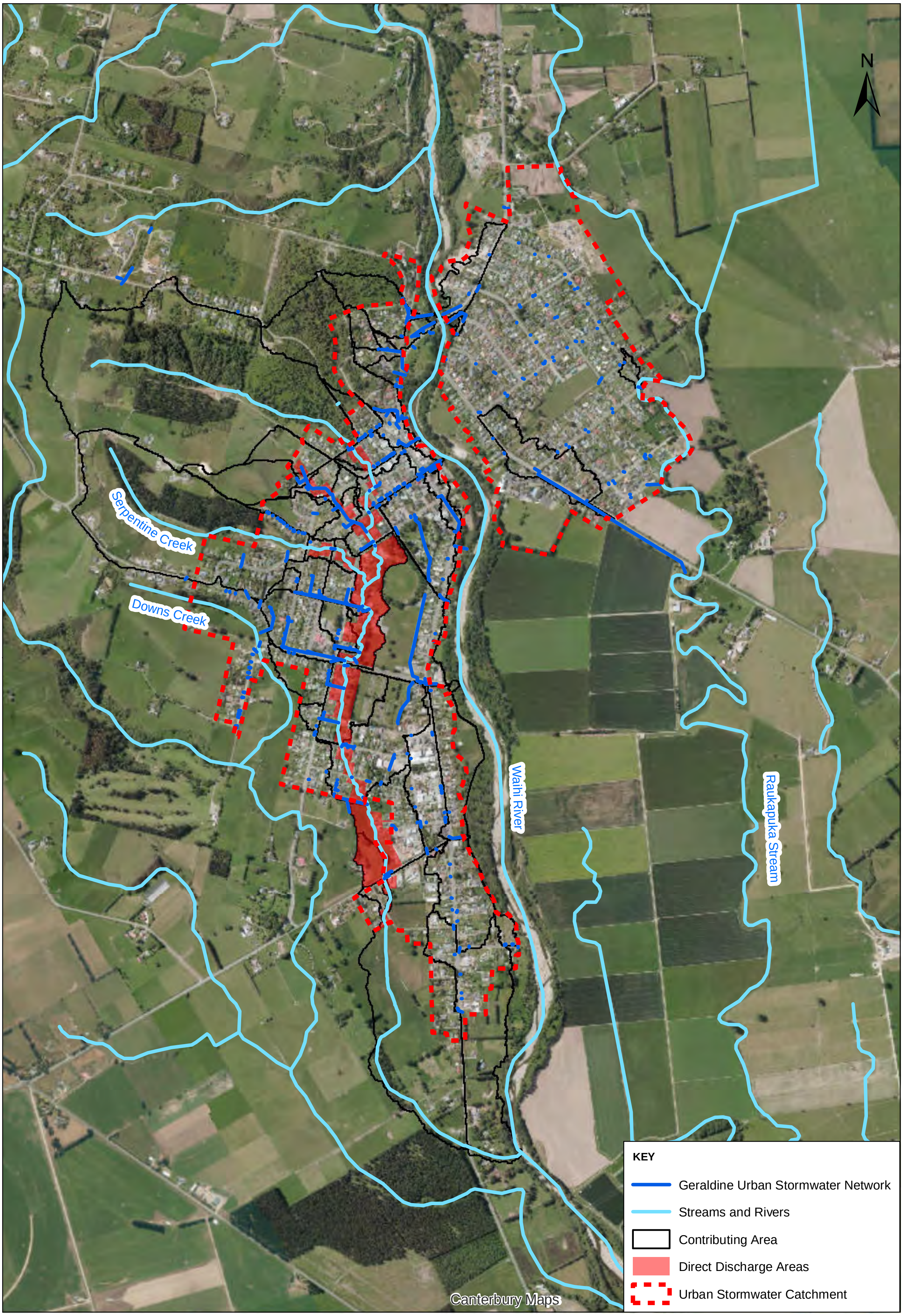
SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 8
CONTAMINANT LOAD MODEL - SOURCES OF TPH BY CATCHMENT

SCALE : 1:20,000 (A4)
0 100 200 400 600 800
METRES

PATTLE DELAMORE PARTNERS LTD

C03489300_CLM_FIGURE8_TPH_Results.mxd AUGUST 2017 ISSUE2



SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 9 : DIRECT DISCHARGE AREAS

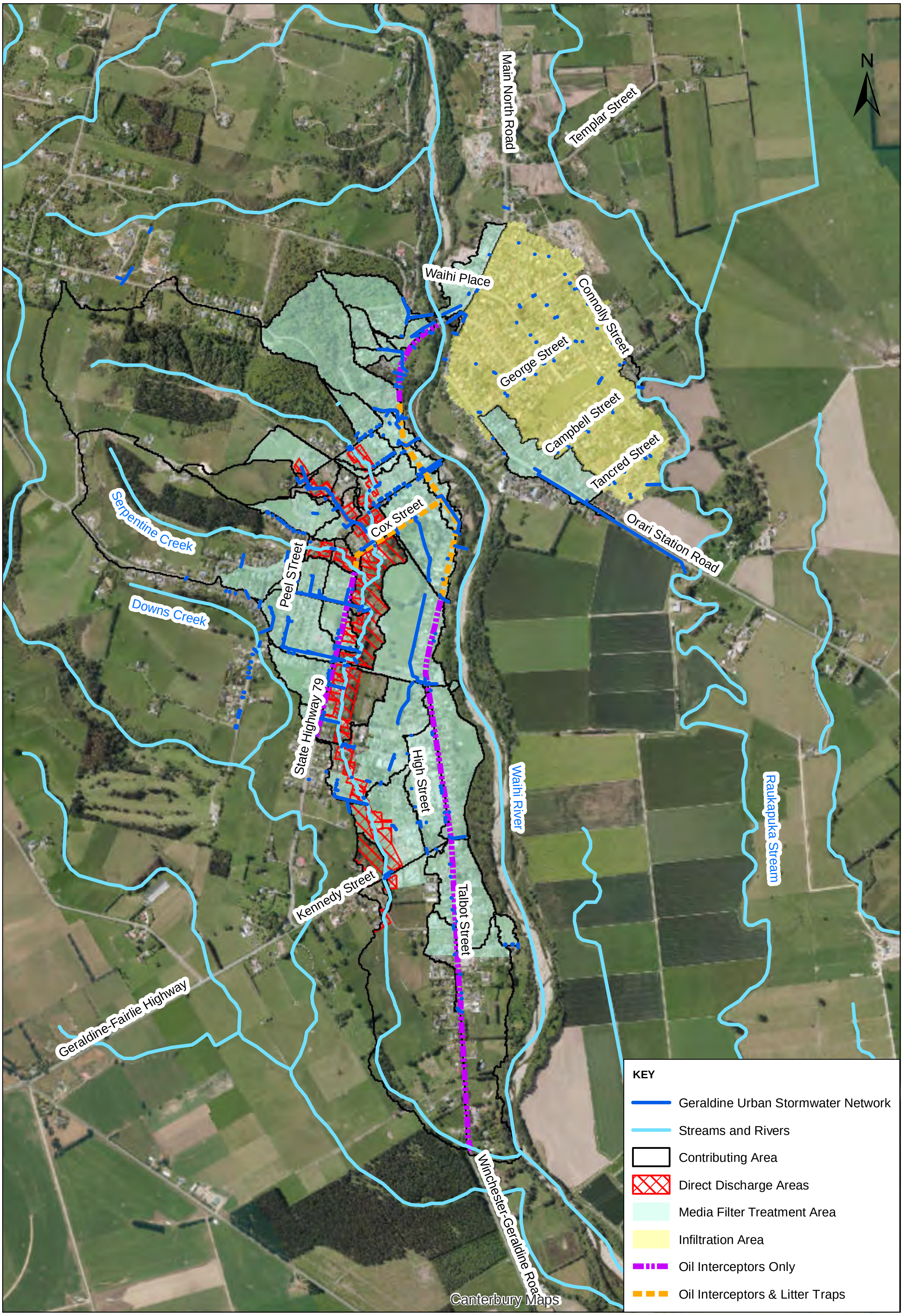
SCALE : 1:20,000 (A4)
0 100 200 400 600 800
METRES

SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 10 : WETLAND CONCEPT

SCALE : 1:20,000 (A4)

0 100 200 400 600 800 METRES



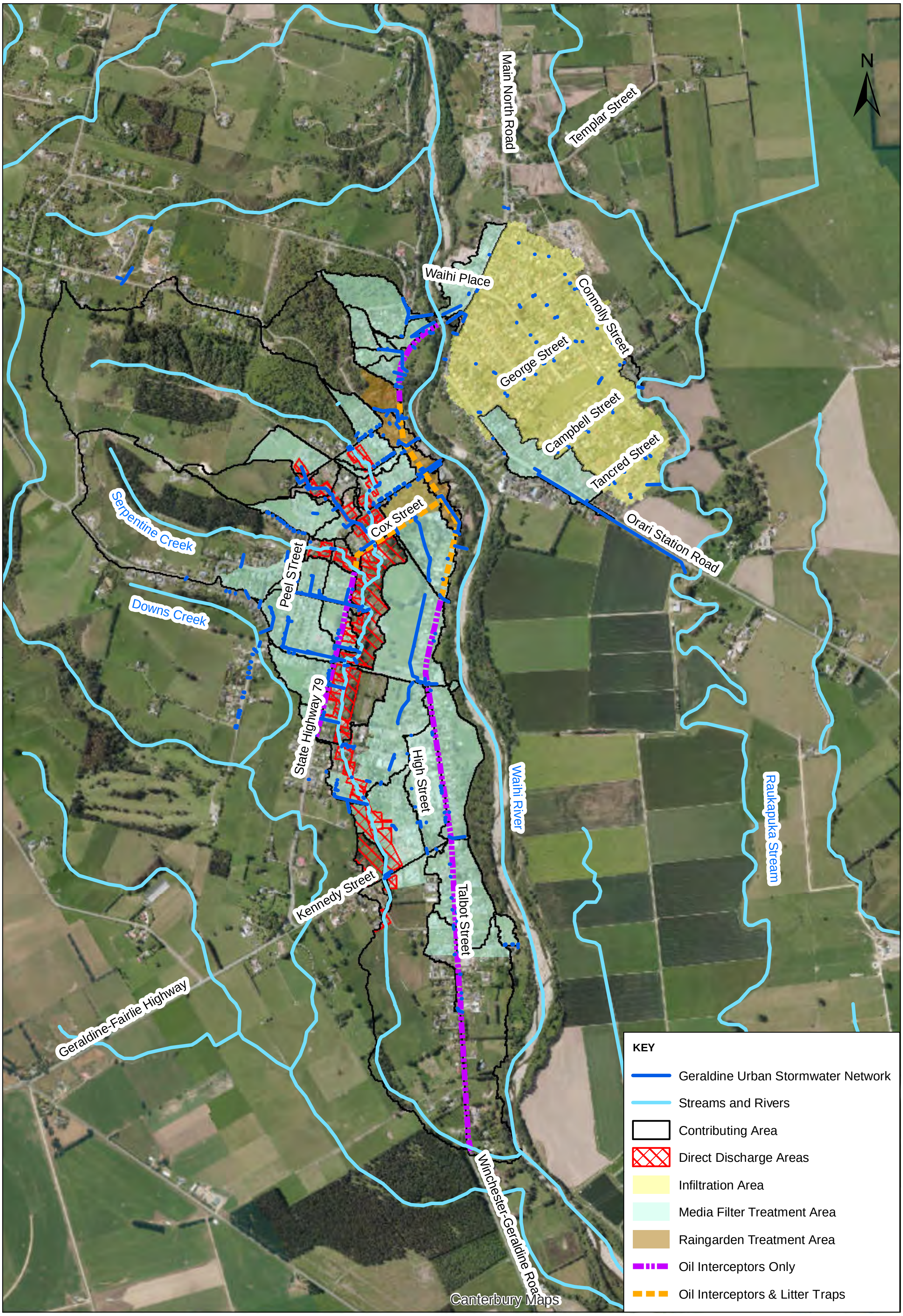
SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 11 : TREATMENT STRATEGY 1

SCALE : 1:20,000 (A4)

0 100 200 400 600 800

METRES

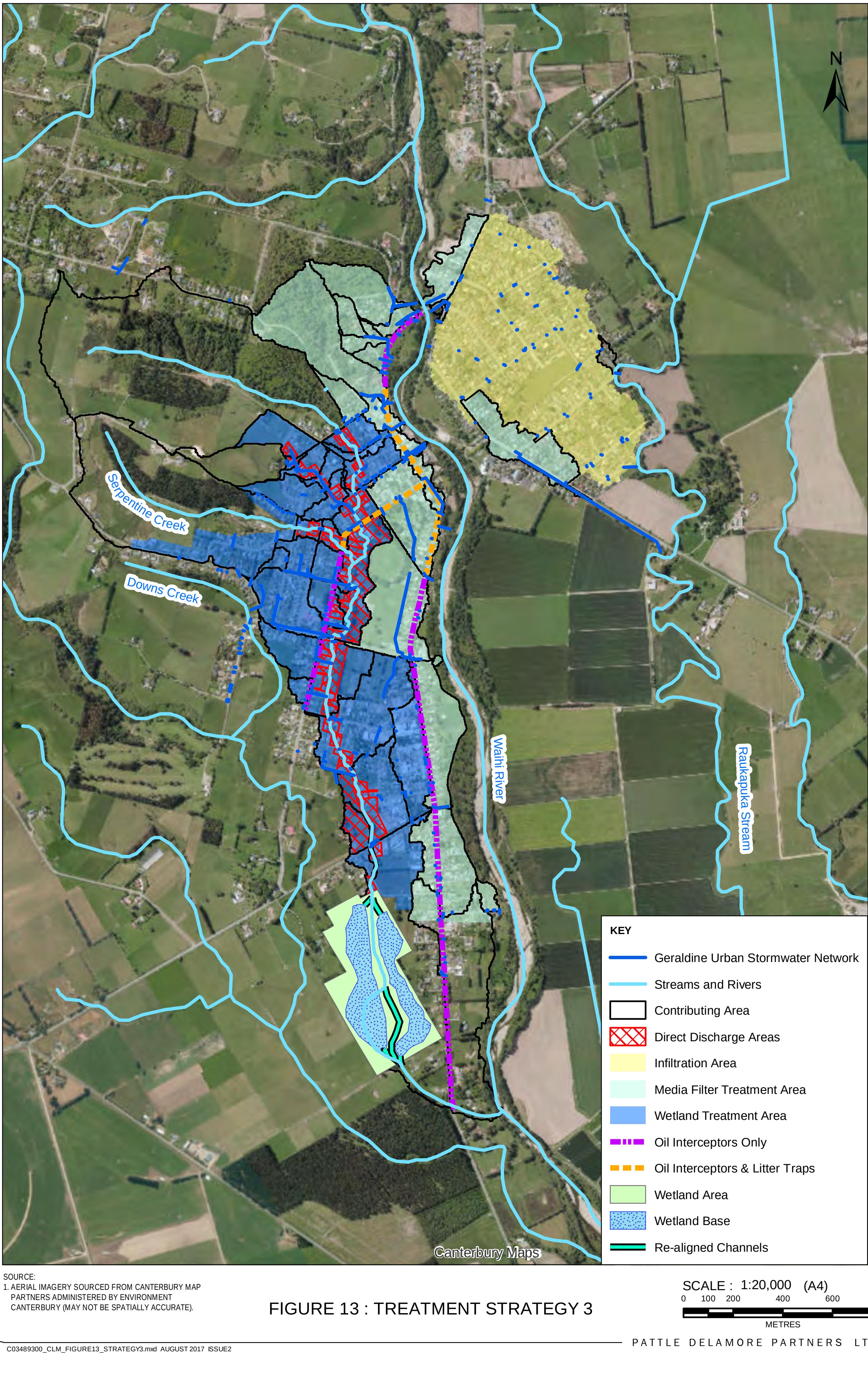


SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 12 : TREATMENT STRATEGY 2

SCALE : 1:20,000 (A4)
0 100 200 400 600 800
METRES

PATTLE DELAMORE PARTNERS LTD



SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 13 : TREATMENT STRATEGY 3

Appendix B

CLM Results Tables

Table B18: Contaminant Loading Results

Contributing Area	TSS[1]		Zinc[1]		Copper[1]		TPH[1]	
	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr	%
0	13,715	7.1%	4.684	6.3%	0.348	5.45%	0.361	1.7%
4	708	0.4%	13.940	18.7%	0.644	10.09%	1.441	6.9%
10	3,412	1.8%	2.664	3.6%	0.209	3.28%	1.449	6.9%
12	338	0.2%	0.379	0.5%	0.120	1.89%	0.642	3.1%
13	1,327	0.7%	1.180	1.6%	0.200	3.14%	0.471	2.3%
15	333	0.2%	0.503	0.7%	0.084	1.32%	0.570	2.7%
16	35,375	18.3%	2.768	3.7%	0.387	6.07%	0.272	1.3%
17	159	0.1%	0.318	0.4%	0.048	0.75%	0.034	0.2%
18	186	0.1%	0.252	0.3%	0.036	0.56%	0.215	1.0%
27	116	0.1%	0.092	0.1%	0.011	0.18%	0.077	0.4%
44	32	0.0%	0.045	0.1%	0.007	0.11%	0.028	0.1%
47	265	0.1%	0.153	0.2%	0.017	0.27%	0.065	0.3%
48	77	0.0%	0.018	0.0%	0.006	0.09%	0.118	0.6%
49	46	0.0%	0.023	0.0%	0.008	0.12%	0.171	0.8%
101	2,225	1.2%	0.363	0.5%	0.050	0.78%	0.240	1.1%
102	415	0.2%	0.100	0.1%	0.022	0.34%	0.359	1.7%
103	692	0.4%	1.680	2.3%	0.144	2.26%	0.978	4.7%
105	6,748	3.5%	1.865	2.5%	0.162	2.54%	0.729	3.5%
106	198	0.1%	1.770	2.4%	0.112	1.76%	0.594	2.8%
107	133	0.1%	1.219	1.6%	0.083	1.30%	0.570	2.7%
109	1,763	0.9%	4.701	6.3%	0.340	5.33%	2.035	9.7%
110	4,936	2.6%	1.240	1.7%	0.169	2.66%	1.338	6.4%
112	5,302	2.7%	2.593	3.5%	0.255	4.00%	1.613	7.7%
113	206	0.1%	2.143	2.9%	0.148	2.31%	1.036	5.0%
118	304	0.2%	0.042	0.1%	0.005	0.08%	0.011	0.1%

Contributing Area	TSS[1]		Zinc[1]		Copper[1]		TPH[1]	
	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr	%
120	757	0.4%	0.297	0.4%	0.017	0.26%	0.006	0.0%
121	1,491	0.8%	5.719	7.7%	0.287	4.50%	0.142	0.7%
131	1,481	0.8%	0.762	1.0%	0.093	1.46%	0.513	2.5%
132	142	0.1%	0.164	0.2%	0.023	0.35%	0.218	1.0%
133	859	0.4%	0.542	0.7%	0.064	1.01%	0.348	1.7%
137	1,882	1.0%	0.550	0.7%	0.073	1.14%	0.380	1.8%
144	208	0.1%	0.128	0.2%	0.013	0.20%	0.003	0.0%
145	356	0.2%	0.634	0.9%	0.094	1.48%	0.093	0.4%
146	445	0.2%	0.652	0.9%	0.096	1.51%	0.417	2.0%
149	333	0.2%	0.527	0.7%	0.074	1.17%	0.081	0.4%
150	1,854	1.0%	0.639	0.9%	0.091	1.42%	0.081	0.4%
151	249	0.1%	0.154	0.2%	0.018	0.28%	0.091	0.4%
153	312	0.2%	0.271	0.4%	0.028	0.44%	0.064	0.3%
155	7,547	3.9%	0.334	0.4%	0.060	0.94%	0.031	0.1%
156	68	0.0%	0.024	0.0%	0.005	0.08%	0.075	0.4%
157	3,364	1.7%	0.329	0.4%	0.045	0.70%	0.051	0.2%
161	123	0.1%	0.788	1.1%	0.046	0.72%	0.116	0.6%
162	310	0.2%	3.275	4.4%	0.179	2.80%	0.130	0.6%
163	339	0.2%	1.481	2.0%	0.089	1.40%	0.052	0.3%
165	86,287	44.7%	3.444	4.6%	0.641	10.04%	0.103	0.5%
171	414	0.2%	0.241	0.3%	0.026	0.41%	0.076	0.4%
1_119	1,364	0.7%	1.593	2.1%	0.204	3.19%	1.642	7.9%
20_21	442	0.2%	0.185	0.2%	0.021	0.33%	0.077	0.4%
8_126_128	2,338	1.2%	5.769	7.8%	0.332	5.20%	0.253	1.2%
McKenzie Street	1,202	0.6%	1.131	1.5%	0.146	2.29%	0.434	2.1%

Notes:

1. *Percentages indicated as fractions of the total catchment loads. Loads are non-cumulative.*

Table B19: Direct Discharges to Serpentine Creek

Contributing Area	TSS		Zinc		Copper		TPH	
	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr	%
0	1.16	5.9%	1.16	24.8%	0.05	15.6%	0.01	1.6%
4	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
12	0.07	17.7%	0.07	18.9%	0.01	6.4%	0.03	4.3%
13	0.00	0.1%	0.00	0.1%	0.00	0.1%	0.00	0.3%
15	0.00	1.3%	0.00	0.8%	0.00	0.6%	0.00	0.8%
16	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
17	0.08	38.1%	0.08	24.1%	0.01	16.2%	0.00	0.0%
18	0.10	42.0%	0.10	37.7%	0.01	25.4%	0.00	0.0%
44	0.01	22.2%	0.01	13.5%	0.00	8.2%	0.00	0.0%
112	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
120	0.52	100.0%	0.52	100.0%	0.03	100.0%	0.01	100.0%
121	0.35	41.7%	0.35	6.2%	0.03	11.6%	0.00	0.0%
131	0.48	27.7%	0.48	62.7%	0.05	49.3%	0.00	0.2%
132	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
133	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
137	0.43	93.0%	0.43	78.0%	0.05	67.5%	0.04	11.0%
144	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
145	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
146	0.20	36.4%	0.20	30.5%	0.02	20.3%	0.00	0.9%
149	0.06	15.6%	0.06	11.1%	0.01	7.7%	0.00	0.3%
150	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
151	0.02	10.3%	0.02	13.2%	0.00	11.0%	0.00	0.0%
153	0.08	24.1%	0.08	30.9%	0.01	28.4%	0.00	0.0%
155	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
156	0.01	15.9%	0.01	35.2%	0.00	17.2%	0.00	0.0%

Contributing Area	TSS[1]		Zinc[1]		Copper[1]		TPH[1]	
	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr	%
157	0.04	1.0%	0.04	12.0%	0.00	8.5%	0.00	0.0%
161	0.00	1.2%	0.00	0.3%	0.00	0.4%	0.00	0.0%
162	0.26	21.5%	0.26	8.0%	0.02	9.4%	0.00	0.0%
163	0.11	26.1%	0.11	7.3%	0.01	11.6%	0.00	0.0%
165	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
1_119	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
20_21	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
8_126_128	0.22	10.0%	0.22	3.8%	0.02	6.6%	0.02	6.3%

Notes:
1. *Percentages indicated as fractions of the contributing area loads. Loads are non-cumulative.*

Appendix C

Supplemental Treatment Device Information

FILTERRA®

Stormwater Bioretention Filtration System

Urban Solution for Water Sensitive Design

The Filterra® System is an innovation in bioretention in its function and application. It has been optimised for high volume/flow treatment and high pollutant removal. Its small footprint allows it to be used on highly developed sites such as landscaped areas, parking lots and streetscapes. Filterra® is exceedingly adaptable and can be used alone or in combination with other BMPs.

filterra® Bioretention Systems

HOW DOES THE FILTERRA® SYSTEM WORK?

Stormwater runoff enters the Filterra® System through a curb-inlet opening and flows through a specially designed filter media mixture contained in a landscaped concrete container. The filter media captures and immobilizes pollutants; those pollutants are then decomposed, volatilized and incorporated into the biomass of the Filterra® System's micro/macro fauna and flora. Stormwater runoff flows through the media and into an underdrain system at the bottom of the container, where the treated water is discharged.

FILTERRA® SYSTEM BENEFITS

Best Value. Filterra® offers the most cost effective stormwater treatment system featuring low cost, easy installation and simple maintenance.

Regulatory Compliance. Third party field testing confirmed that Filterra® meets state regulatory requirements for pollutant removal under TAPE and TARP testing. (Two of the most well recognised US stormwater testing programmes.)

Aesthetics. Landscaping enhances the appearance of your site making it more attractive while removing pollutants.

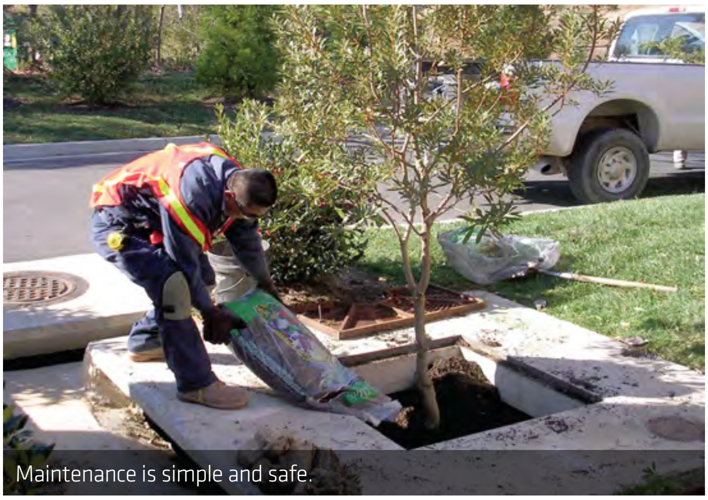
Maintenance. Maintenance is simple and safe (no confined space access).

Versatile. Filterra® is ideal for both new construction and urban retrofits, as well as:

- Streetscapes
- Parking lots
- Highways
- Urban settings
- Daylighted Roof drains
- Industrial settings

FILTERRA® FEATURES

- Small Footprint
- Pre-engineered design
- Media protected during construction
- QA/QC program in media manufacture
- LEED points
- Sustainable design

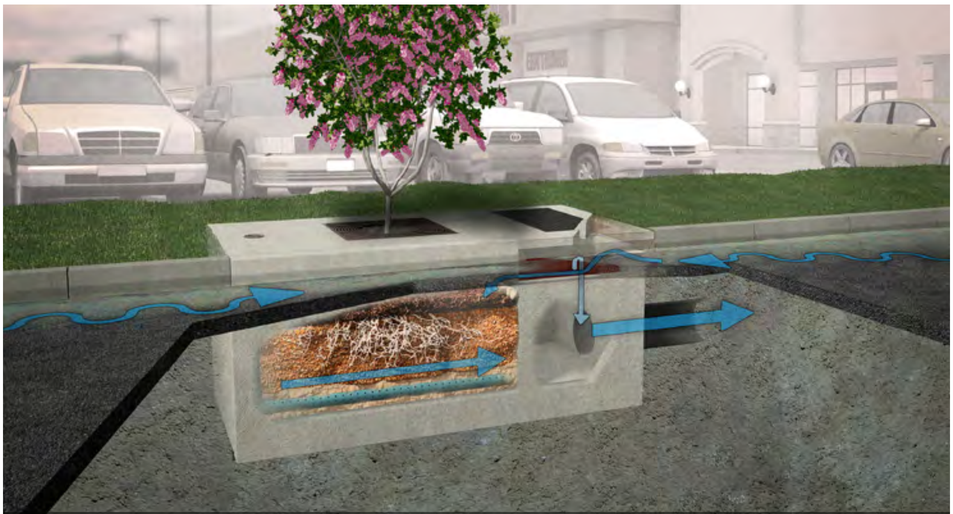


Maintenance is simple and safe.

www.stormwater360.co.nz

BETWEEN SKY AND SEA

FILTERRA® CONFIGURATIONS



Filterra® with internal bypass

Filterra® and ChamberMaxx providing treatment, detention and retention

Street Tree Filterra®

A HIGHLY EFFECTIVE SYSTEM

Filterra® is well-suited for the ultra-urban environment with proven high removal efficiency for many toxic substances such as petroleum and heavy metals.

Expected Pollutant Removal

(Ranges Varying with Particle Size, Pollutant Loading and Site Conditions)

TSS Removal	85%
Phosphorus Removal	60% - 70%
Nitrogen Removal	43%
Total Copper Removal	> 58%
Dissolved Copper Removal	46%
Total Zinc Removal	> 66%
Dissolved Zinc Removal	58%
Oil & Grease	> 93%

Information on the pollutant removal efficiency of the filter soil/plant media is based on third party lab and field studies.

CONTACT DETAILS

Stormwater360

FREEPHONE:
0800 STORMWATER
(0800 786769)

www.stormwater360.co.nz

Stormwater360®
BETWEEN SKY AND SEA

The Stormwater Management StormFilter® Performance Summary

CONTECH® STORMWATER SOLUTIONS INC.

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Stormwater Management StormFilter® Performance

Table of Contents

CONTECH STORMWATER SOLUTIONS INC.

Filtration Products

CONTECH Stormwater Solutions provides filtration Best Management Practices (BMPs) designed to meet the most stringent regulatory requirements for stormwater treatment. Our products remove the most challenging target pollutants using sustainable media – including total suspended solids (TSS), soluble heavy metals, oil and grease, and total nutrients. Product field-proven performance has earned hundreds of standalone BMP approvals from regulatory agencies nationwide.

Target Pollutants

- Total suspended solids
- Soluble heavy metals
- Oil and grease
- Total nutrients
- Organic toxicants

Applications

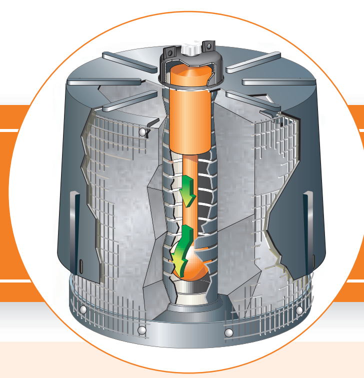
- Commercial, municipal, and industrial sites
- High-density and single-family residential sites
- Maintenance, transportation and port facilities
- Parking lots
- Arterial roads
- Bridges

Why Filtration?

- Provides the highest treatment level of any standalone, passive BMP
- Meets the most stringent regulatory requirements
- Scalable cartridge-based design allows sizing to meet project requirements
- Targets site-specific pollutants with customized filtration media
- HS-20 rated, underground BMPs maximize land use

About CONTECH Stormwater Solutions

When you select CONTECH Stormwater Solutions, you'll get much more than stormwater management products. You'll have dedicated, knowledgeable engineers and technical experts to help you select the right technology to meet your regulations. Our organization is committed to preserving water resources by providing customized, site-specific stormwater treatment solutions. And, every product is backed by the most comprehensive lab, field and independent testing in the industry. As one of the four divisions of CONTECH Construction Products – Stormwater, Bridge, Earth Stabilization, and Drainage – we bring you the most comprehensive portfolio of solutions in the industry. Every day. Every site.



The Stormwater Management StormFilter®

- Siphon-actuated filtration
- Surface cleaning mechanism extends maintenance intervals
- Uniform sediment loading increases cartridge longevity
- Five optimized configurations fits different applications
- Cartridge-based system provides exact sizing
- Dry sump means no water to remove during maintenance
- Extensive field verification studies prove performance

Filtration

CONTECH STORMWATER SOLUTIONS INC.

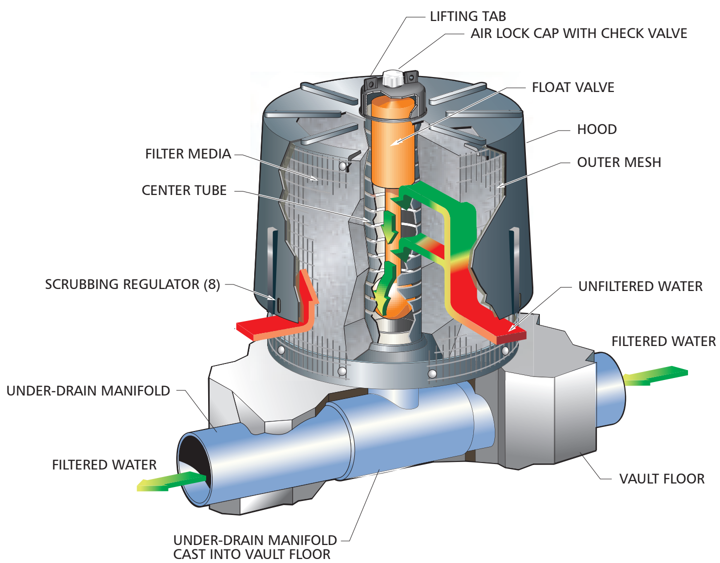
StormFilter

Siphon-actuated filtration

Designed to meet stringent regulatory requirements, The Stormwater Management StormFilter® targets a full range of pollutants in urban runoff. Using a variety of sustainable media and passive filtration, the StormFilter effectively removes TSS, soluble heavy metals, oil and grease, and total nutrients.

The patented surface cleaning system prevents surface blinding and extends the cartridge life cycle as well as maintenance intervals. The StormFilter is cost-effective, highly reliable, and easy to install.

From small, pre-fabricated catch basins to large box culvert and panel vaults, StormFilter systems are installed underground, leaving valuable land available for development. The compact design also reduces construction and installation costs by limiting excavation.

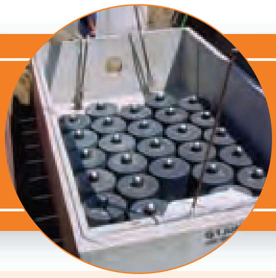


How does it work?

The StormFilter is a passive, siphon-actuated, media-filled filter cartridge that traps and adsorbs particulates and pollutants.

During a storm, runoff passes through the filtration media and starts filling the cartridge center tube. Air below the hood is purged through a one-way check valve as the water rises. When water reaches the top of the float, buoyant forces pull the float free and allow filtered water to drain.

After the storm, the water level in the structure starts falling. A hanging water column remains under the cartridge hood until the water level reaches the scrubbing regulators. Air then rushes through the regulators releasing water and creating air bubbles that agitate the surface of the filter media, causing accumulated sediment to drop to the vault floor. This patented surface-cleaning mechanism helps restore the filter's permeability between storm events.



Vault StormFilter

- Site-specific design treats the water quality storm
- Engineered to simplify the entire stormwater system and lower overall cost
- Easy installation — arrives on-site fully assembled

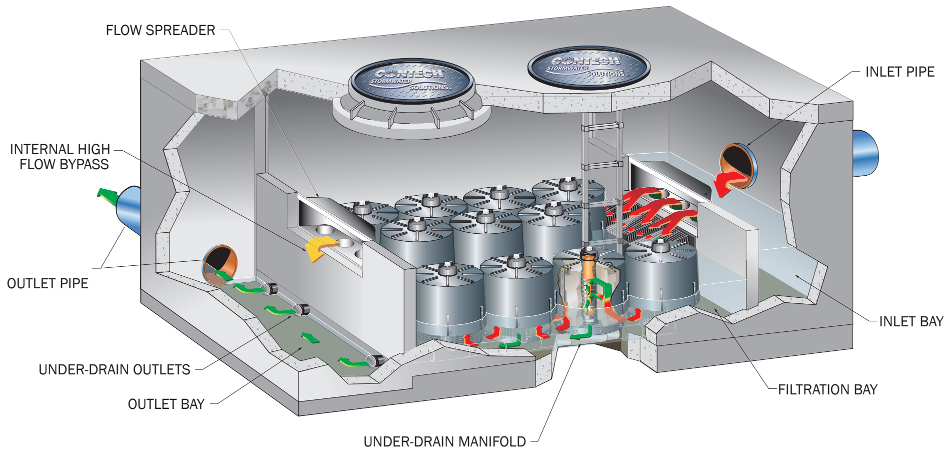
High Flow StormFilter

- One structure for easy installation
- Sized to meet the site-specific treatment rate for lower capital, installation and maintenance costs
- Reduces labor and site work associated with cast-in-place designs

Volume StormFilter

- Volume-based
- Configured as an entire system or partial system (pretreatment captures the WQv; filtration flow control)
- Low cost installation — precast components simplify installation

CONTECH® STORMWATER SOLUTIONS INC.

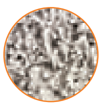


The Stormwater Management StormFilter®

- An array of filtration media targets site-specific pollutants
- Designed for maintenance cycles of one year or longer so your filtration system remains active all year long
- Flow-based and volume-based systems available to fit regulations on your project
- Pre-manufactured designs make installation easier, save you time and money
- Cartridge-based systems provide exact sizing for every project
- Dry, or nearly dry, between storm events with optional Drain-Down — no water to remove during maintenance

Media Choices

Our filtration products can be customized using different filter media to target site-specific pollutants. A combination of media is often recommended to maximize pollutant removal effectiveness.



Perlite is naturally occurring puffed volcanic ash. Effective for removing TSS, oil and grease.

CSF® Leaf Media and MetalRx™ are created from deciduous leaves processed into granular, organic media. CSF is most effective for removing soluble metals, TSS, oil and grease, and neutralizing acid rain. MetalRx, a finer gradation, is used for higher levels of metal removal.

Zeolite is a naturally occurring mineral used to remove soluble metals, ammonium and some organics.

GAC (Granular Activated Carbon) has a micro-porous structure with an extensive surface area to provide high levels of adsorption. It is primarily used to remove oil and grease and organics such as herbicides and pesticides.

	Perlite	CSF	MetalRx	Zeolite	GAC
Sediments	✓💧	✓			
Oil and Grease	✓💧	✓	✓		
Soluble Metals		✓	✓	✓💧	
Organics		✓	✓		✓💧
Nutrients	✓	✓	✓	✓	

✓-StormFilter Application 💧-VortFilter Application

Note: Indicated media are most effective for associated pollutant type. Other media may treat pollutants, but to a lesser degree.

CatchBasin StormFilter

- Low cost, ideal for small sites with stringent regulations
- Low hydraulic profile
- 3-in-1 design: Catch basin, high flow bypass, filtration BMP
- Easy installation — arrives on-site fully assembled

Curb-Inlet StormFilter

- Low drop filtration meets stringent treatment regulations on low drop sites
- Curb inlet installs out of the roadway, and treats sheet flow as it enters the stormwater system
- 3-in-1 design reduces costs and simplifies design

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CONTECH STORMWATER SOLUTIONS INC.

Parameter Brief

Summary of Field Performance Evaluation of the Stormwater Management StormFilter® for Removal of Total Suspended Solids

Introduction

The Washington State Department of Ecology (Ecology) and the New Jersey Department of Environmental Protection (NJDEP) have established individual statewide certification programs for the evaluation and approval of stormwater best management practices (BMPs). The certification programs establish guidelines and protocols for meeting state regulatory stormwater treatment requirements and define analytical methods for the evaluation of suspended solids removal efficiency.

The Stormwater Management StormFilter® (StormFilter) is the first manufactured BMP to receive stand-alone approval by both NJDEP and Ecology for meeting state requirements for removal of total suspended solids (TSS). Summaries of the certification programs and the StormFilter field evaluations are included below.

Field Evaluation Programs

Technology Assessment Protocol – Ecology

In 2002, Ecology established the Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE) for evaluating stormwater BMPs. The primary objective of the TAPE is to characterize BMP effectiveness in removing pollutants from stormwater in accordance with the performance claims and treatment goals outlined by Ecology (Table 1).

The TAPE technology evaluation process determines use-level designations for each BMP technology. Where an emerging technology is not in widespread use, a Pilot Level Designation may be assigned, allowing limited use in order to demonstrate performance in the field. If the technology has substantial performance data, Ecology may grant a Conditional Use Level Designation, defining a period when field testing per the TAPE must be completed in order to obtain a General Use Level Designation (GULD). A GULD confers a general acceptance for the technology as it has satisfied Ecology's treatment goals per the TAPE.

The technology evaluation process that leads to a GULD from Ecology involves several elements beyond the execution of a field-monitoring program. The applicant must implement a Quality Assurance Project Plan (QAPP), outlining the monitoring program specifics in accordance with the TAPE. In addition to the QAPP, the applicant must submit an independent Technology Evaluation Engineering Report (TEER) to Ecology for review and approval (WADOE, 2004). The TEER is a third-party document that evaluates performance claims and field results, and then recommends use-level designations. Representatives from Ecology and local municipalities participate in a Technical Review Committee that is responsible for reviewing BMP performance documentation and providing additional approval recommendations to Ecology.

Technology Acceptance Reciprocity Partnership - Tier II Protocol

The State of New Jersey is a member of the Technology Acceptance Reciprocity Partnership (TARP), a joint effort between six states to share information on the performance of emerging BMP technologies. The TARP Tier II Protocol for Stormwater Best Management Practice Demonstrations (TARP Tier II Protocol) provides standards for evaluating stormwater technologies (TARP, 2003).

The NJDEP has developed a BMP certification program for performance claims in accordance with the TARP Tier II Protocol. The New Jersey Corporation of Advanced Technology (NJCAT) verifies laboratory and field performance claims and the NJDEP reviews and certifies the NJCAT verification.

CONTECH Stormwater Solutions, Inc. (CONTECH) began the process of obtaining product approval for the StormFilter in New Jersey by seeking verification from NJCAT. The initial application prompted extensive laboratory evaluation, yielding substantive performance claims (CONTECH, 2001). The laboratory evaluation was verified by NJCAT and used to support a Conditional Interim Certification, issued by NJDEP.

A requirement of Conditional Interim Certification is the execution of field monitoring conducted in accordance with the TARP Tier II Protocol to verify field performance claims relative to laboratory claims (TARP, 2003). The Greenville Yards Industrial Park Field Evaluation Project Plan was accepted by NJCAT and NJDEP as TARP Tier II compliant and monitoring activity began in June 2004 (CONTECH, 2004). Upon successful completion of field monitoring, NJCAT issues a Field Verification, followed by Final Certification from NJDEP. The NJDEP performance goal for stand-alone treatment is listed in Table 1.

Table 1: Ecology Performance Goals for Basic Treatment

Jurisdiction	Category (mg/L)	Goal
Ecology	Influent TSS-WA EMC < 100	Effluent EMC ≤ 20 mg/L
	Influent TSS-WA EMC > 100	80% Removal
NJDEP	TSS	80% Removal

Field Evaluation Site Descriptions

Washington Field Evaluations

Two field evaluations were conducted as part of the performance assessment of the StormFilter in the State of Washington. The Heritage Marketplace (HMP) StormFilter system treats runoff from 4 acres of primarily impervious asphalt surrounding a commercial retail center in Vancouver, WA. The Lake Stevens North (LSN) StormFilter system is adjacent to Lake Stevens and drains an area of 0.29 acres of impervious road bridge decking and roadway. Table 2 provides a summary of the monitoring sites and StormFilter systems.

The Heritage Marketplace and Lake Stevens field evaluations involved 18 months of monitoring, providing sufficient TSS removal to support Ecology's basic treatment requirements for the StormFilter (SMI, 2004a; SMI, 2004b).

Table 2: Summary of field monitoring site conditions

Site Name	Location	WQ Flow Rate (cfs)	Specific Flow Rate (gpm/ft^2)	Unit Size (ft)	Media	No. of Cartridges	Site Description
Heritage Marketplace	Vancouver, WA	0.38	1	8 x 16	ZPG	23	Commercial
Lake Stevens	Everett, WA	0.17	1	6 x 12	ZPG	10	Roadway
Greenville Yards	Jersey City, NJ	0.90	2	8 x 18	Perlite	27	Commercial

New Jersey Field Evaluation

Greenville Yards (GYS) is a commercial warehouse complex in Jersey City, NJ. This complex generates runoff from over 10 acres of pavement and ultimately drains to the New York Harbor. As a regional boat, rail, and truck-shipping hub, this complex sees constant activity and receives heavy traffic. Table 2 provides a summary of the monitoring site and the StormFilter system.

Monitoring at the Greenville Yards Field Evaluation Project lasted for an 18-month period and involved the collection of 16 storm events representing 17.13 inches of precipitation (CONTECH, 2006a). The performance data collected provided sufficient TSS removal to verify the overall performance of the StormFilter.

Particle Size Distribution

Washington

Ecology defines TSS as sediment less than 500 microns measured by the Suspended-Sediment Concentration method (ASTM 3977-97), and it is referred to as TSS-WA. Ecology's laboratory testing standard uses Sil-Co-Sil-106, a manufactured silica sand, as the benchmark for evaluating a silt loam texture. The particle size distributions at these field monitoring sites are representative of the high silt content of stormwater runoff (silt loam) that is characteristic of the Pacific Northwest (SMI, 2004a; SMI, 2004b) (Figure 1).

New Jersey

New Jersey uses EPA Method 160.2 to measure TSS. Particle size distribution was evaluated in order to verify that the suspended solids collected at the Greenville Yards monitoring site were representative of the soils characteristic of New Jersey (Figure 1) (NJDEP, 2006). Based upon the average of three separate assessments, solids were characterized as a sandy loam texture, with a sand, silt and clay distribution of 59%, 34% and 7%, respectively (CONTECH, 2006b).

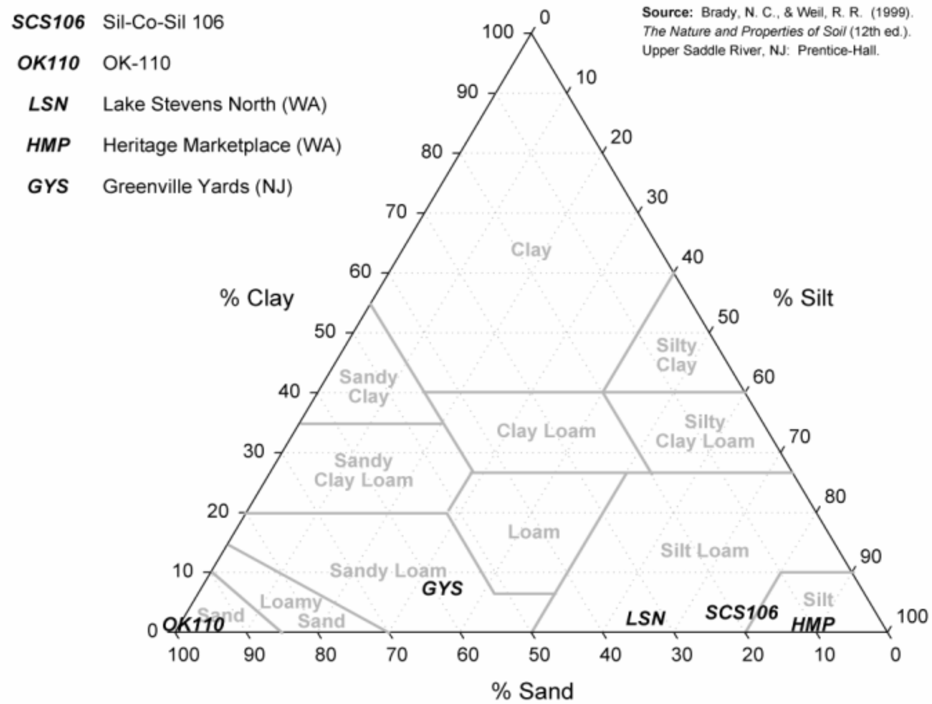

Figure 1: Ternary plot of sediment textures.

Summary of Performance

The performances of the StormFilter in field evaluation programs in Washington and New Jersey are summarized below (Table 3). The StormFilter installations met the performance goals for soils of a silt loam texture operating at 1 gpm/ft^2 and of a sandy loam texture operating at 2 gpm/ft^2. Storm events with influent EMCs greater than 100 mg/L exceeded the performance goal of 80% TSS removal at each field evaluation site. For influent concentrations less than 100 mg/L, an effluent goal of 20 mg/L was satisfied.

Conclusion

Different land use types and rainfall distributions require different stormwater treatment technologies to protect water quality and meet local regulatory requirements. The StormFilter was evaluated at commercial and roadway sites in a Type IA rainfall distribution in Washington. In New Jersey, field evaluation was conducted at a commercial site in a Type II rainfall distribution. TAPE and TARP Tier II technology certification programs determined the effectiveness of the StormFilter at removing suspended solids in stormwater. Because soil texture, land use, and rainfall characteristics vary, it is important to incorporate local and regional conditions into consideration when applying technology evaluation programs.

The TAPE and TARP Tier II certification programs defined the requirements for the StormFilter to achieve approval as a stand-alone BMP. The StormFilter has been evaluated in the field at varying operating rates, with different media, and under varying land use types and rainfall distributions. In Washington, the StormFilter systems met the requirements for TSS removal as defined by Ecology. In January 2005, Ecology issued the StormFilter a General Use Level Designation as a basic treatment device for TSS removal, operating at a specific flow rate of 1 gpm/ft2 (7.5 gpm per cartridge for an 18-inch cartridge) using ZPG™

(zeolite/perlite/granular activated carbon) media for a silt loam texture. In May 2007, NJDEP issued a Final Certification of the StormFilter system as a stand-alone system for TSS removal, operating at a specific flow rate of 2 gpm/ft2 (15 gpm per cartridge for an 18-inch cartridge) using perlite media for a sandy loam soil texture. NJDEP and NJCAT found the StormFilter field evaluations satisfied the TARP Tier II requirements.

Through the TAPE and TARP Tier II evaluation programs, the StormFilter is the first proprietary device approved as an effective, stand-alone stormwater BMP for TSS removal, and is the only manufactured BMP approved under both of these nationally recognized programs.

Table 3: Summarized performance for the StormFilter field evaluations in Washington and New Jersey. [1]

Field Evaluation Sites		
Site Description	**GYS**	**HMP and LSN (pooled data)**
Land Use	Commercial	Commercial and Roadway
Location	NJ	WA
Soil Texture	Sandy loam	Silt loam
Specific Flow Rate (gpm/ft²)	2	1
Qualifying Storm Events	*n* = 16	*n* = 22
Data Summary		
TSS Influent EMC	**Median Effluent EMC (mg/L)**	
< 100 mg/L	12	19
≥ 100 mg/L	25	33
	Suspended Solids Reduction (%)	
All	80*	82
< 100 mg/L	73	61
≥ 100 mg/L	82	89

***** NJCAT verified regression of EMC ($P < 0.001$)

[1] Raw data available from CONTECH Stormwater Solutions, 2007

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CONTECH STORMWATER SOLUTIONS

Parameter Brief

Total Suspended Solids (TSS) Removal Using Different Particle Size Distributions with the Stormwater Management StormFilter®

Introduction

Total Suspended Solids (TSS) is commonly used in the stormwater industry as a surrogate pollutant and a measure of Best Management Practice (BMP) performance. Although a practical standard, it is becoming evident that the measurement of TSS can be complex. Historically, parameters such as particle size distribution and specific gravity have not been included as part of BMP performance due to the difficulty of measuring these parameters in the field. For example, in a situation where road-sanding material is being washed into a BMP, the removal of 80% of TSS is easily achieved as the majority of the mass of the particles is composed of large sand and grit particles with a high specific gravity. In other situations, the TSS particles are much finer and have lower specific gravity, such as runoff from parking lots and high travel roads that frequently have "gray" water resulting from suspensions of silts, tire and brake dust, and associated fractions of oil and grease at low concentrations.

TSS Definitions

CONTECH Stormwater Solutions Inc. (CONTECH) has been investigating various particle size distributions (PSDs) for BMP acceptance or verification for various agencies: Washington State Department of Ecology (Ecology), New Jersey Corporation for Advanced Technology (NJ CAT), New Jersey State Department of Environmental Protection (NJ DEP), City of Portland, OR Bureau of Environmental Services (BES).

Five different PSDs are presented in Table 1. These particle sizes consist of natural soils (sandy loam and silt loam), manufactured sediment (SIL-CO-SIL 106), and two protocols for evaluating stormwater (APWA and City of Portland BES). The StormFilter was tested with the natural soils and SIL-CO-SIL sediments (finer distribution than the APWA or BES protocols). PSD testing was predominantly conducted in the CONTECH laboratory using simulated stormwater in a TSS concentration range between approximately 0 – 350 mg/L.

CONTECH would recommend that a jurisdiction define TSS with a range of PSDs such as the sandy loam, silt loam, or SIL-CO-SIL 106 used in these laboratory investigations, as opposed to a uniform PSD (i.e. 80% removal of 125 microns). Manufactured sediments are commercially available and can easily be used in comparing different BMPs. The PSDs are idealized at a specific gravity of 2.65, while field studies by CONTECH clearly show a high fraction of the TSS as organic in texture (seasonally) with a specific gravity at approximately 1.0. Investigations by CONTECH show that PSDs in the Pacific Northwest tend to be characteristic of silt loams and PSDs in the NE tend to be sandy loams or loamy sands, especially where road sanding is practiced.

Table 1 has a summary of various PSDs that have been investigated by CONTECH. For further information, Appendix A contains the graphical representation of each sediment type. Table 2 contains the TSS removal performance with these different sediments.

Table 1. Sediment Particle Size Distributions

Particle Size (microns)	Percent by mass (approximate)				
	Sandy loam [a]	Silt loam [a]	SIL-CO-SIL 106 [b]	APWA 1999 Protocol [c]	Portland BES [c]
500 – 1000	5.0	5.0	0	20.0	10.0
250 – 500	5.0	2.5	0	10.0	10.0
100 – 250	30.0	2.5	0	35.0	25.0
50 –100	15.0	5.0	20.0	10.0	25.0
2 – 50	40.0	65.0	80.0	25.0	30.0
1 – 2	5.0	20.0	0.0	0	0

[a] CONTECH tested Oregon silt and sandy loams for New Jersey Corporation for Advanced Technology verification of TSS performance claims.

[b] CONTECH tested SIL-CO-SIL 106 for Washington State Department of Ecology per the Technology Assessment Protocol – Ecology (2001).

[c] Hypothetical particle size distributions from these testing protocols. Particle sizes were presented in a range available in Appendix A; the table represents the least conservative (coarser) approximate particle size range.

Table 2. TSS removal using differing particle size distributions

Media Type	Cartridge Flow Rate (gpm)	Percent Removal (%)			PSD Effectiveness
		Sandy loam [a]	Silt loam [a]	SIL-CO-SIL 106 [a]	SIL-CO-SIL 106 (lowest micron)
Standard Perlite	15	77 - 80		72 – 78	10
Standard Perlite	7.5			78 – 83	7
Coarse Fine Perlite	15				
Coarse Fine Perlite	7.5		68 – 75	79 – 82	7
Fine Perlite	15			73 – 78	10
Fine Perlite	7.5			85 – 88	6
CSF® leaf [b]	15		68 – 79		
Coarse Perlite/Zeolite [c]	15		63 – 84		
ZPG™	15			80 – 82	7
ZPG™	7.5			86 – 89	5
PhosphoSorb™	15			80 – 84	7
PhosphoSorb™	7.5			87 – 89	6
Perlite/CSF® leaf	7.5			82 – 86	6
Perlite/Metal Rx™	7.5			89 – 92	5
Granular Activated Carbon	7.5			89 – 92	5

[a] Linear regression was used in the data analysis, the table presents the upper and lower 95% confidence limits. Data was collected in the CONTECH laboratory using simulated stormwater for TSS concentrations between 0 – 350 mg/L. Silt and sandy loam performance data was NJCAT-verified.

[b] Performance of the CSF leaf media was tested using both field and laboratory investigations. Laboratory studies used a Palatine loam sediment. Field data is from the Pacific Northwest.

[c] Performance of the coarse perlite / coarse zeolite media was tested using a Palatine loam sediment. Reported in Total Suspended Solids Removal using StormFilter Technology.

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Revision

RS-0091	1/20/10	Added PhosphoSorb™ to Table 1.
RS-0091	12/27/07	Added lowest micron threshold to Table 2.
RS-0091	07/27/07	Added GAC to Table 1.
RS-0091	04/14/06	Rebranded to Contech Stormwater Solutions, Inc.
PD-03-13.4	09/08/05	Added Standard Perlite at 15 and 7.5 gpm, and ZPG at 15 gpm to Table 1. Updated Reference Section.
PD-03-13.3	04/28/05	Added Perlite/CSF leaf & Perlite/MetalRX to Table 1. Updated Reference Section.
PD-03-013.2	12/02/04	Added ZPG™ to Table 1.
PD-03-013.1	12/15/03	Altered Table 1 - SIL-CO-SIL to reflect 20:80:0 (sand:silt:clay) Added content to section 2, paragraph 3, last sentence.
PD-03-013.0	10/28/03	

APPENDIX A

SIL-CO-SIL 106 Particle Size Distribution

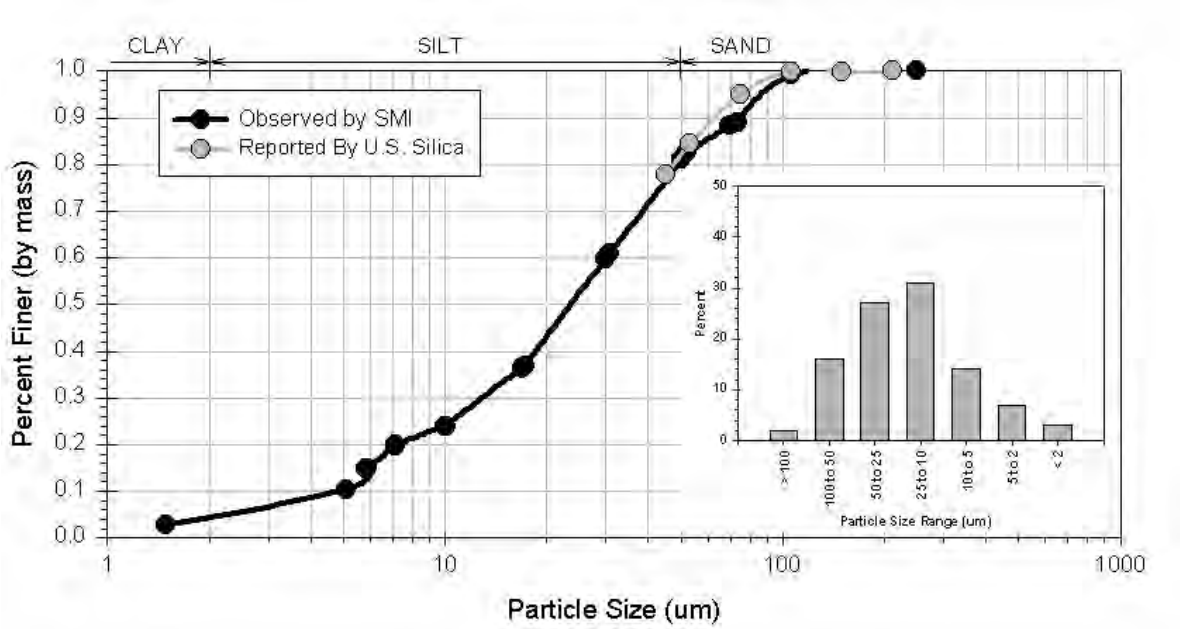

Figure 1. Particle size distribution for SIL-CO-SIL 106. Sand/silt/clay fractions according to USDA definitions are approximately 20%, 80%, and 0% for SIL-CO-SIL 106, indicating that the texture corresponds to a silt material. Specific gravity is 2.65.

Silt Loam Particle Size Distribution

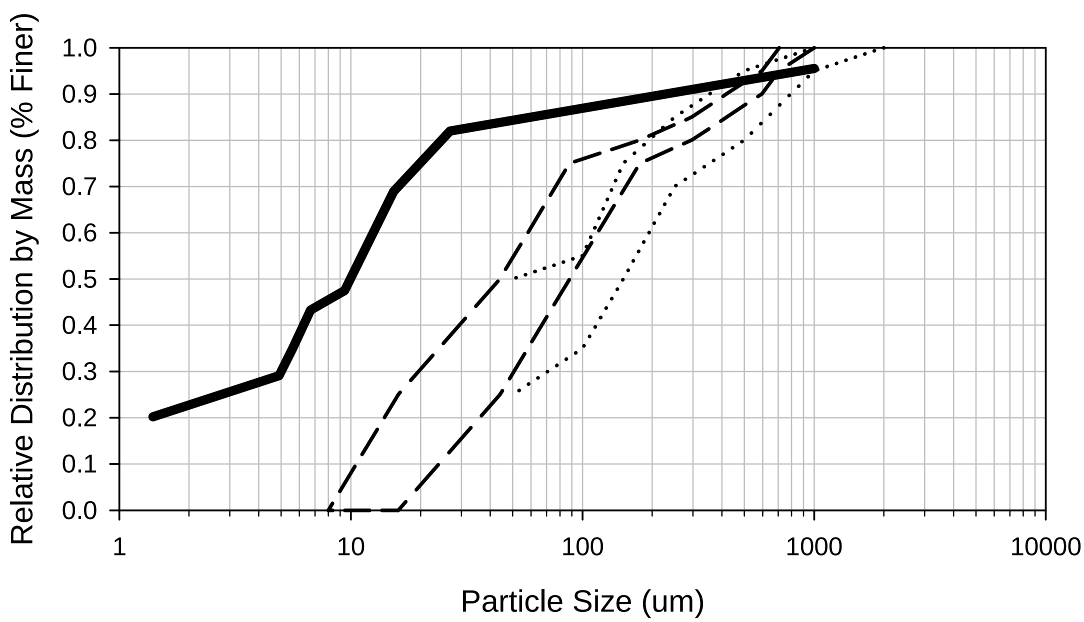

Figure 2. Particle size distribution (shown as solid line) for bulk soil sample "OSU Silt Loam GPS W.P. #10" used for testing. Sand/silt/clay fractions according to USDA definitions are approximately 15%, 65%, and 20%, indicating that the texture corresponds to a silt loam material. Dashed and dotted lines indicate particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

Sandy Loam Particle Size Distribution

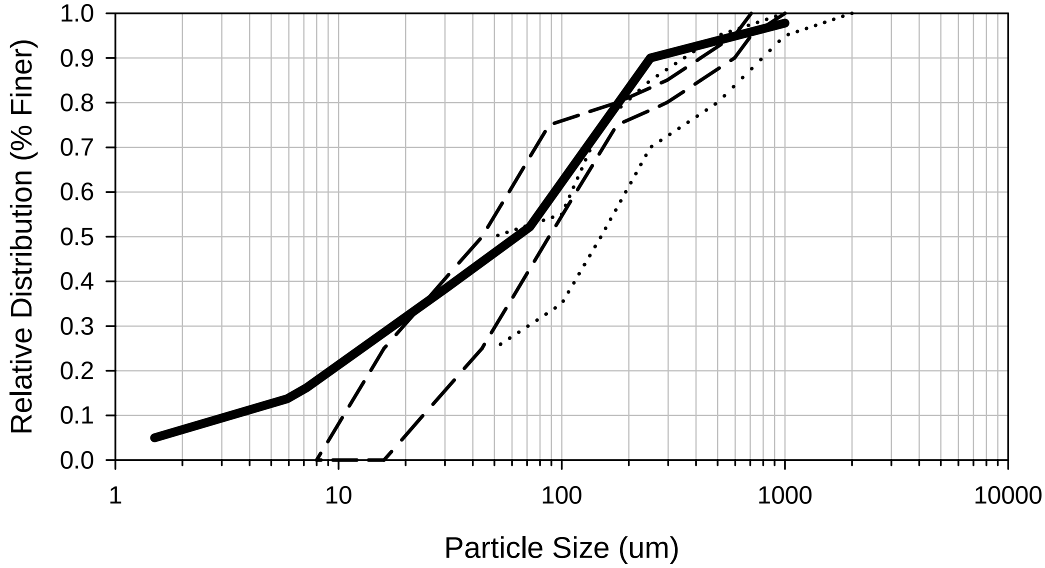

Figure 3. Particle size distribution (shown as solid line) for bulk soil sample "OSU Loam GPS W.P. #13" used for testing. Sand/silt/clay fractions according to USDA definitions are approximately 55%, 40%, and 5%, indicating that the texture corresponds to a sandy loam material. Dashed and dotted lines indicate particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

Parameter Brief

Total Phosphorus Removal:
Comparing the Performance of the Stormwater Management StormFilter® and Sand Filters

Summary

Two media filters, the Stormwater Management StormFilter® (StormFilter) and sand filters were compared for the removal of total phosphorus. Nine different sites with 110 paired influent and effluent samples were evaluated. For the sand filter, 52 paired samples were retrieved from the International Stormwater BMP Database (BMP database) for five sites. For the StormFilter, 58 paired samples were analyzed from four peer reviewed and/or independent studies. Regression of Event Mean Concentration (EMC) results indicates that there was no statistical difference between the StormFilter (64% mean removal: 95% confidence limits 54% and 74%) and sand filter (67% mean removal: 95% confidence limits 52% and 83%) for the removal of total phosphorus.

Introduction

Total phosphorus (TP), expressed in milligrams/liter is the sum of particulate organic phosphorus, particulate inorganic phosphate, dissolved inorganic phosphorus (ortho-phosphate), and dissolved organic phosphorus. Organic phosphates are a part of plants and animals, their wastes or decomposing remains. Inorganic phosphate originates from decomposing mineral materials and man-made fertilizer products. TP concentrations in stormwater are variable but range from 0.01 to 7.3 mg/L (Minton, 2002).

Removal of phosphorus can be accomplished by three mechanisms. The first is removal of organic and inorganic phosphorus associated with solids. The second is removal by biological uptake by plants or bacteria. The third is through chemical precipitation such as the reaction of ortho-phosphate with iron to form iron phosphate in aerobic conditions. Both the StormFilter and sand filters primarily remove TP by the removal of solids and can be amended with alternative media like iron to target ortho-phosphate.

Approach

Sand filter data were retrieved from the International Stormwater BMP Database (www.bmpdatabase.org) on September 30, 2005. A total of six sand filter investigations that included TP - all roadway sites - were available from the BMP Database. Only five sites were utilized in this comparison. One sand filter site (I-5/SR-78 P&R – Vista, CA) contained a large variance in data and demonstrated poor performance (-167% aggregate load removal) that was not consistent with the other investigations, and thus was omitted from the analysis. The only criterion for selection was paired influent and effluent samples with the assumption that the BMP database has screened and assured data integrity. The data set represents storm events that were sampled from April 1999 to May 2001.

Data used for the StormFilter were collected from four sites that have been either independently tested and/or peer-reviewed. The criteria used for StormFilter data selection was that a final, completed evaluation report was issued as of October 1, 2005; all information has been peer-reviewed; and each investigation evaluated a stand-alone, flow-based StormFilter system using ZPG (Perlite/Zeolite/Granular Activated Carbon) or Perlite/Zeolite (PZ) media. Three investigations contained ZPG media, while one investigation contained PZ media. Only 5% by volume of the ZPG media contains granular activated carbon. Since 95% of ZPG and PZ media are the same, they were deemed comparable for the purpose of the analysis. The data set represents storm events that were sampled from November 2001 to March 2004.

The peer review entities and/or third party investigators with report titles were:

- NSF International in cooperation with U.S. EPA, Wisconsin Department of Natural Resources under the Environmental Technology Verification Program.
    - "Environmental Technology Verification Report. Stormwater Source Area Treatment Device. The Stormwater Management StormFilter Using ZPG Filter Media." NSF International, 2005.
- City of South Lake Tahoe in conjunction with the Tahoe Regional Planning Agency.
    - "StormFilter Performance Analysis prepared for the City of South Lake Tahoe, CA." 2nd Nature Environmental Science + Consulting, 2005.
- State of Washington Department of Ecology and APWA Surface Water Managers Technical Review Committee. Resource Planning Associates provided a Technical Engineering Evaluation Report regarding Quality Assurance/Quality Control and confirmed analysis in accordance with the Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE) for Basic Treatment.
    - "Heritage Marketplace Field Evaluation: Stormwater Management StormFilter with ZPG Media." Stormwater Managment Inc., 2004a.
    - "Lake Stevens North Field Evaluation: Stormwater Management StormFilter with ZPG Media." Stormwater Managment Inc., 2004b.

Table 1. General Site Description for the StormFilter sites

Location	Media	WQ Flow Rate (cfs)	Unit Size	No. of Cartridges	Surface Area of Media (ft^2)	Individual Cartridge Flow rate (gpm)	Site Description
Vancouver, WA	ZPG	0.50	8 x 16	23	168	7.5	Shopping Center
Lake Stevens, WA	ZPG	0.23	8 x 16	10	73	7.5	Roadway
S. Lake Tahoe, CA	PZ	1.65	CIP	50	365	15	Resort
Milwaukee, WI	ZPG	0.30	6 x 12	9	66	15	Roadway

Table 2. General Site Description for the sand filter sites

Location	Media	WQ Flow Rate (cfs)	Surface Area of Media (ft^2)	Site Description
Whittier, CA	sand	NA	291	Roadway
Escondido, CA	sand	NA	291	Roadway
Monrovia, CA	sand	NA	431	Roadway
Carlsbad, CA	sand	NA	776	Roadway
Norwalk, CA	sand	NA	614	Roadway

NA – Not Available

Site Description

Tables 1 and 2 provide summaries of the general site descriptions available for the StormFilter and sand filter evaluated for the comparison. Limited information was available from the BMP database regarding the sand filters.

Data Analysis Method

Data were compared using Regression of EMC (REMC). Linear regression statistics similar to those suggested by Martin (1988) and URS et al. (1999) were used to estimate the mean TP removal efficiency. Instead of using calculated load values as suggested by Martin (1988), regressions were performed on EMC values alone so as to avoid any error associated with the storm volume data. REMC is a quantitative data analysis method that uses parametric statistics. REMC provides 95% confidence intervals and is more robust than using qualitative data analysis methods such as the Line of Comparative Performance, Discrete Removal Efficiencies, or Aggregate Load methods that can be subject to interpretation or require non-parametric statistical tools, such as a sign test. REMC analysis estimates the mean removal efficiency over a range of influent concentrations, and thus yields a continuous series of normal distributions. Resulting standard deviations can thus be used to statistically compare performance.

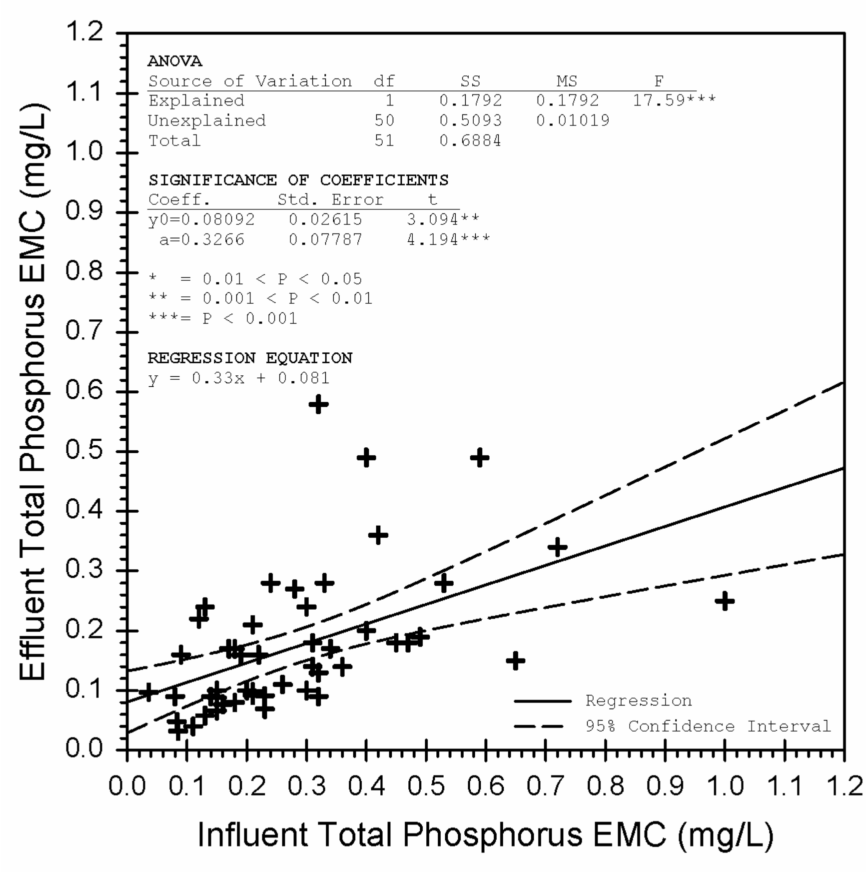

Figure 1. **Sand filter** data analyzed using Regression of EMC for Total Phosphorus (TP) removal representing 52 paired influent and effluent samples at 5 roadway sites and demonstrating a mean removal efficiency estimate of 67% with 95% confidence intervals of 52% and 83%. Data was statistically significant at the P <0.001 level.

Results

Figures 1 and 2, and Table 3 summarize the data analyzed using REMC. Figures 1 and 2 provide detailed statistical analysis. Table 3 provides general descriptive statistics. Both media filters had similar influent concentrations, with the sand filter data containing a higher median influent concentration (0.23 mg/L) than the StormFilter data (0.16 mg/L).

Figure 1 and Table 3 indicate that the performance of the sand filter for five roadway sites evaluated in California achieved a mean removal efficiency of 67% with 95% confidence intervals for the mean removal efficiency of 52% and 83%. A grand total of 52 storm events were sampled, and eight data points had an effluent concentration higher than the influent concentrations. The sand filter demonstrated a statistically significant removal (P<0.001; 99.9% probability of net removal) of TP.

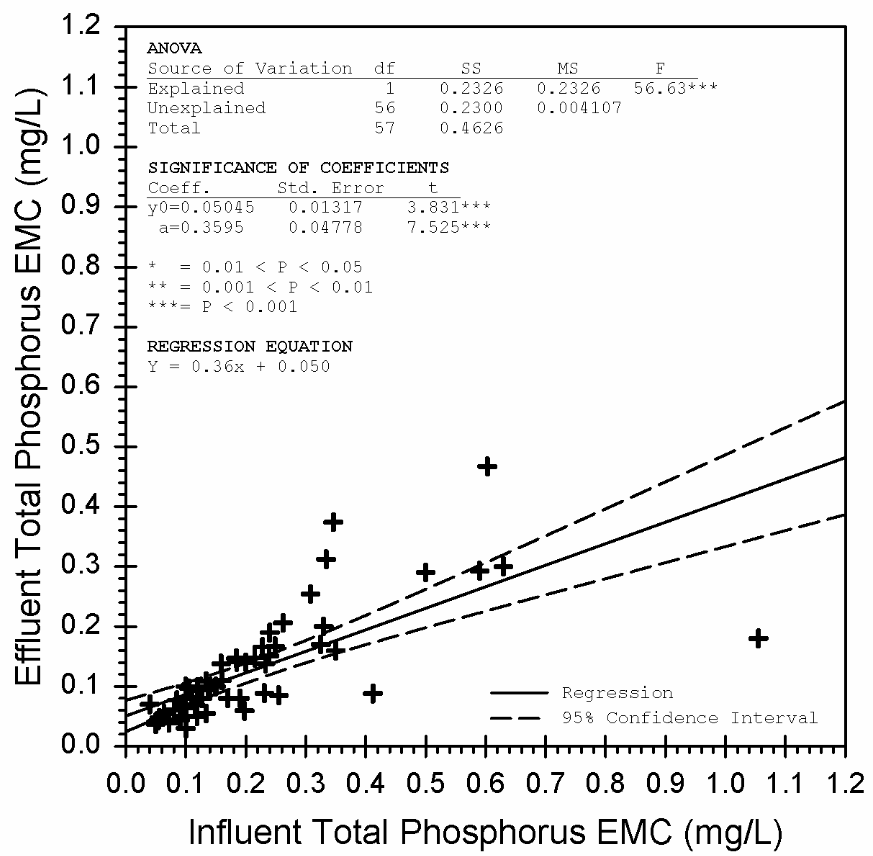

Figure 2. **StormFilter** data analyzed using Regression of EMC for Total Phosphorus removal representing 58 paired influent and effluent samples at 4 sites and demonstrating a mean removal efficiency estimate of 64% with 95% confidence intervals of 54% and 74%. Data was statistically significant at the P <0.001 level.

Figure 2 and Table 3 represent the StormFilter data using ZPG or PZ media at four sites for 58 storm events. The total phosphorus mean removal efficiency using linear regression was 64% with 95% confidence limits of 54% and 74%. Two data points that were included in the analysis had effluent concentrations greater than the influent concentrations. Overall the StormFilter system demonstrated statistically significant removal (P<0.001; 99.9% probability of net removal) of TP.

In Figure 3, StormFilter and sand filter data were compared using the estimated mean and standard deviation of the sample populations. When comparing these distributions, a one-tailed or two-tailed test is used to determine the cumulative probability of Type I and Type II errors (i.e. the probability of wrongly rejecting or wrongly accepting the null hypothesis) in the statistical analysis. In this instance, Figure 3 graphically demonstrates that the StormFilter data is 99.6% within the sand filter 95% confidence intervals. Thus, there is no significant difference (P=0.05) between the performance of the StormFilter and sand filter for total phosphorus removal.

Table 3. Total phosphorus removal statistical information for the StormFilter and sand filters. Sand filter data were retrieved from the International Stormwater BMP Database. StormFilter data were from four sites (Milwaukee Riverwalk, Ski Run Marina, Heritage Marketplace, and Lake Stevens) using ZPG or Perlite/Zeolite media.

	Descriptive Statistics			Regression of EMC			
Filter type	*n*	Range of Influent EMCs (mg/L)	Median Influent EMC (mg/L)	Mean Removal Efficiency Estimate (%)	95% Confidence Interval for the Mean Removal Efficiency Estimate (%)	Median Effluent EMC Estimate (mg/L)	95% Confidence Interval for the Median Effluent EMC Estimate (mg/L)
Sand Filter	52	0.04 to 1.00	0.23	67***	52 to 83	0.16	0.13 to 0.19
StormFilter	58	0.04 to 1.06	0.15	64***	54 to 74	0.11	0.09 to 0.12

*** = P < 0.001

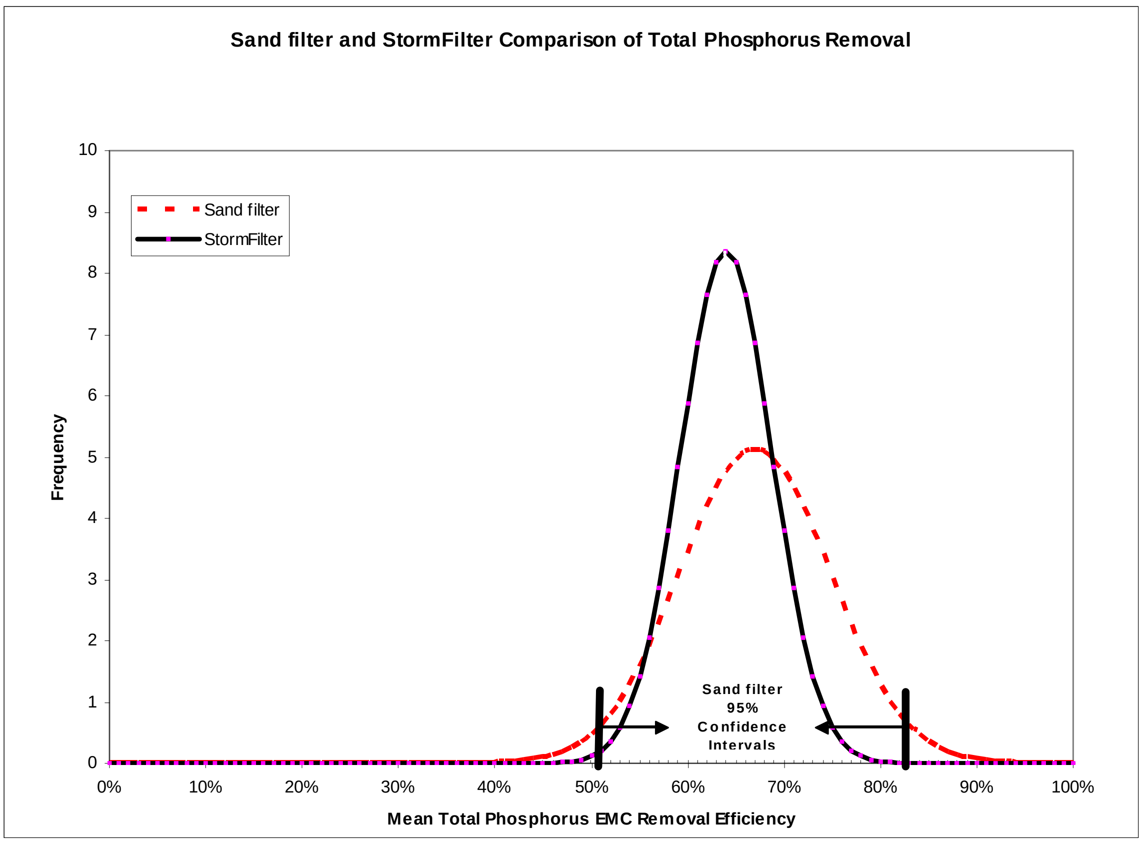

Figure 3. A comparative analysis of the StormFilter and sand filter data that displays the probability distribution of the mean total phosphorus removal performance of these two types of media filters. A total of 9 sites, each data set containing over 50 storm events were used in the comparison. The overlap of the two bell shaped curves indicate that there is no statistical difference between the performance of the StormFilter and sand filters for the removal of total phosphorus.

Conclusion

Two media filters, sand filter and StormFilter, displayed similar TP removal performance when analyzing the data with REMC and comparing the standard deviation and the distributions of these sample populations. Although the sand filter demonstrated a higher mean (+3%) than the StormFilter, the StormFilter exhibited more precise range of performance (standard deviation (SD) = 10) than the sand filter (SD = 15). Therefore, these two media filters can be said to have equivalent performance for the removal of total phosphorus.

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Product Evaluation

Evaluation of the Stormwater Management StormFilter® system for the removal of total nitrogen:

Kearny Mesa Maintenance Station case study

Overview

This study summarizes the ability of a Stormwater Management StormFilter® (StormFilter) system installation to remove nitrogen compounds from stormwater runoff. Only limited data exist documenting the total nitrogen removal performance of the StormFilter system. Presently, the only study that has documented the total nitrogen removal of a StormFilter system over the course of multiple storm events is the California Department of Transportation 3-year study of the Kearny Mesa Maintenance Station (KMMS) site. The KMMS StormFilter system contains 79 coarse perlite/coarse zeolite cartridges operating at 15 gpm/cartridge and treats 1.5 acres of a road equipment maintenance facility. Based upon data collected between March 1999 and April 2001, total nitrogen removal is evident.

Background on Nitrogen

Nitrogen is a very dynamic and biologically important element. It is an integral part of protein, and thus is omnipotent in water bodies associated with biologically rich environments. Except for most saltwater ecosystems and some desert aquatic environments (environments that are nitrogen limited), nitrogen is usually present in quantities that exceed what is needed for biological productivity, allowing phosphorus availability to dictate productivity instead (phosphorus limited). Although it is possible for stormwater BMPs to demonstrate the removal of nitrogen compounds during an individual storm event, retention of nitrogen by these systems over time is a much more important issue (Scheuler, undated).

In chemical terms, nitrogen in stormwater is usually present in 2 forms: organic nitrogen and inorganic nitrogen. Total nitrogen encompasses the sum of these nitrogen compounds. Each of these forms of nitrogen is susceptible to different removal mechanisms, though removal can often be complicated by the transformation of one nitrogen compound into another following capture. Thus, in determining the nitrogen removal potential of a specific stormwater BMP, it is necessary to first understand the various nitrogen compounds and the mechanisms by which they can be removed from an aquatic system.

Organic nitrogen (organic-N) describes biogenic nitrogen compounds such as protein, urea, and nucleic acids. It can be measured by quantifying the total kjeldahl nitrogen (TK-N) content of a sample minus the ammonia-N concentration. TK-N assesses the ammonification potential of the nitrogen compounds in a sample and thus detects biogenic nitrogen as well as existing ammonia-N, hence the need to account for the pre-existing ammonia-N. Since bulk biological solids contain a substantial quantity of organic cellular material, the removal of such solids can result in the removal of some fraction of the nitrogen load encountered by a system. The removal of fine biological solids such as bacteria and cells, as well as the removal of dissolved organic nitrogen compounds such as urea and protein, is much more difficult and not easily accomplished through settling or screening. While per-storm removal is possible and documented, the challenge of removing solid-phase organic-N as solids from stormwater lies in preventing the digestion and eventual processing of this material into other, more difficult to remove, nitrogen compounds.

Inorganic Nitrogen (inorganic-N) is usually broken down into oxidized nitrogen compounds and reduced nitrogen compounds. These two types of inorganic nitrogen have very different characteristics.

Oxidized nitrogen compounds of importance in aquatic environments are nitrate-N (NO_3^--N) and nitrite-N (NO_2^--N). These are oxidized, anionic, inorganic forms of nitrogen that are highly soluble in water, with NO_3^--N being the predominant compound and NO_2^--N being an intermediate. These oxidized forms of nitrogen are the usual fate of other nitrogen compounds in aerobic aquatic environments such as stormwater runoff. The solubility and stability of these nitrogen compounds makes their removal a challenge, and the only high volume commercial process that is currently available for oxidized nitrogen removal is anaerobic digestion wherein denitrification (NO_3^--N → NO_2^--N → N_2 gas) is performed by specific anaerobic microbes—an intensive, controlled process. While these microbes are naturally occurring and probably present to some degree in most stormwater BMPs, their effectiveness is dependent upon basic environmental parameters such as temperature and oxygen content, making their effectiveness both random and seasonal.

Where nitrate-N and nitrite-N represent important oxidized, inorganic forms of nitrogen, ammonia-N is the most important reduced form of inorganic nitrogen. As with the oxidized forms of nitrogen, NH_3-N is highly water soluble. While most often referred to as ammonia-N, in solution it is most often present as ammonium-N (NH_4^+-N), though reference to ammonia-N will be continued in this document. Unlike the oxidized forms of nitrogen, NH_3-N is highly toxic and volatile, which makes it the nitrogen compound of most concern in aquatic ecosystems. In oxic, aquatic environments, NH_3-N is rapidly transformed into oxidized nitrogen via biochemical nitrification processes (NH_3-N → NO_2^--N → NO_3^--N). This is the primary mechanism utilized in aquaculture to address nitrogen toxicity issues, whereas nitrogen load issues are addressed through frequent water changes wherein water high in nitrogen is discharged and replaced with water with lower nitrogen concentrations. However, when water bearing NH_3-N is passed through a medium with cation exchange properties, both toxicity and load issues associated with NH_3-N can be addressed.

While the Stormwater Management StormFilter® (StormFilter) is susceptible to the same total nitrogen removal challenges (i.e. uncontrollable nitrogen transformations, sensitivity of biological natural attenuation functions to environmental conditions) encountered by engineered surface water ecosystems, it has some distinct advantages. The availability of cation exchange media, the dewatering characteristics of the system, and the physical removal of used cartridges and the associated captured materials from the site all provide the potential for the substantial reduction of the total nitrogen load of a system on an annual basis (assuming annual maintenance). Maintenance assures the true removal of the contaminants from a system since stormwater BMPs capture and store non-biodegradable contaminants such as metals, inorganic solids, and nutrients.

Unfortunately, evaluation of the total nitrogen removal capabilities of a stormwater BMP requires monitoring of all three nitrogen compounds discussed above for an extended period of time. All three compounds must be monitored because organic-N captured during one event may degrade into NH_3-N between events and gradually leave the system as NO_3^--N over the course of subsequent storm events. The need to track total nitrogen loads over time also makes extended monitoring imperative as the loss of previously captured nitrogen is a gradual process which is difficult to monitor if substantial data gaps exist. Conducting monitoring for an extended period of time will account for seasonable variables such as temperature, water chemistry, microbial activity, and nutrient loading, which all affect the biochemical transformation of nitrogen compounds and thus system performance.

Procedure

Monitoring data for this system is publicly available from the National Stormwater BMP Database (www.bmpdatabase.org) and was used to evaluate the total nitrogen removal potential of a StormFilter system.

Results

Using paired influent and effluent EMC data for TK-N and NO_3^--N obtained from the National Stormwater BMP Database, the performance of the system was summarized using the Regression of EMC method ($y_0 \neq 0$) (SMI, 2002). Unlike the Regression of Load method, the Regression of EMC method limits the incorporation of errors associated with flow measurement by assuming that influent volume equals effluent volume—a logical assumption for flow-through stormwater BMPs such as the StormFilter. Figures 1 and 2 illustrate the summarized removal efficiencies for TK-N and NO_3^--N, respectively. Based upon this data summarization method, mean TK-N removal efficiency demonstrated by the KMMS StormFilter system was 31% (P=0.05: L1=39%, L2=23%), and mean NO_3^--N removal efficiency was observed to be 21% (P=0.05: L1=39%, L2=4%).

Assuming that the NO_2^--N is either insignificant or accounted for (see Discussion), the TK-N and NO_3^--N EMCs can be combined to produce the total nitrogen EMC. Under this assumption, total nitrogen influent and effluent EMCs were calculated using the data presented in Figures 1 and 2. The extrapolated total nitrogen data is shown in Figure 3 and evaluated using the Regression of EMC method. It yields a mean total nitrogen removal efficiency of 27% (P=0.05: L1=35%, L2=18%).

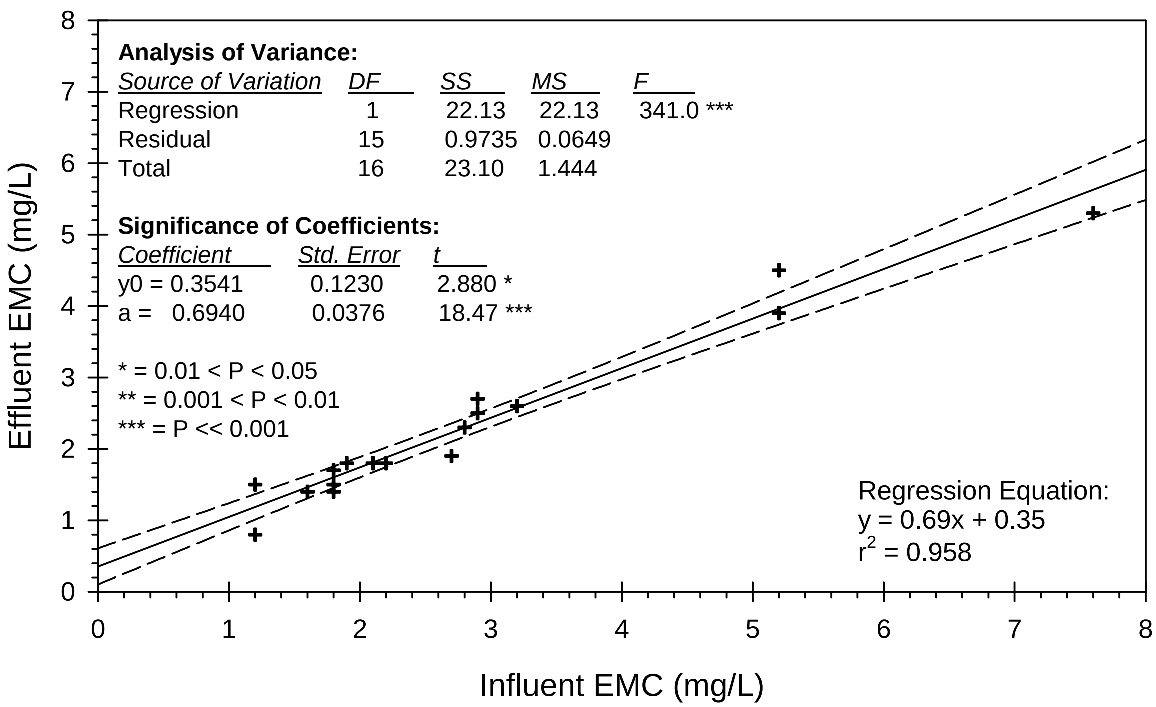

Figure 1. Total Kjeldahl Nitrogen (TK-N) EMC data for the KMMS StormFilter system with coarse perlite/coarse zeolite cartridges with a design flow rate of 15 gpm/cartridge. Using the regression of EMC performance evaluation method, TK-N removal is determined by subtracting the regression slope from 1 and thus estimated to be 31% (P=0.05: L1=39%, L2=23%).

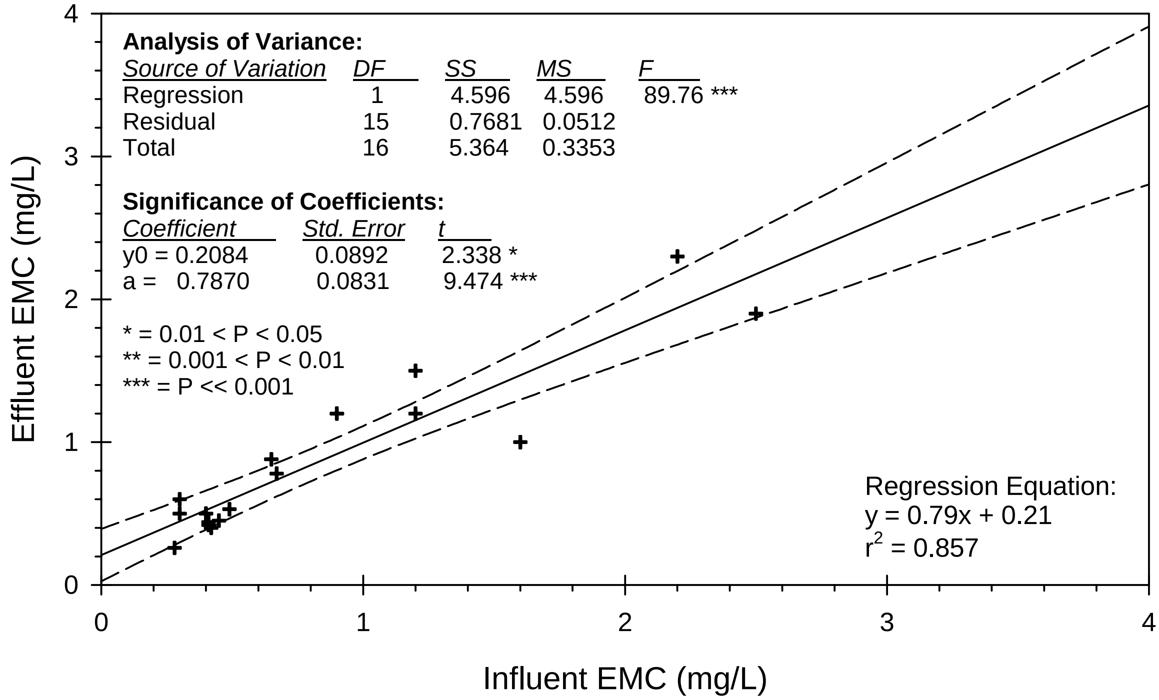

Figure 2. Nitrate Nitrogen (NO_3^--N) EMC data for the KMMS StormFilter system with coarse perlite/coarse zeolite cartridges with a design flow rate of 15 gpm/cartridge. Using the regression of EMC performance evaluation method, NO_3^--N removal is estimated to be 21% (P=0.05: L1=39%, L2=4%).

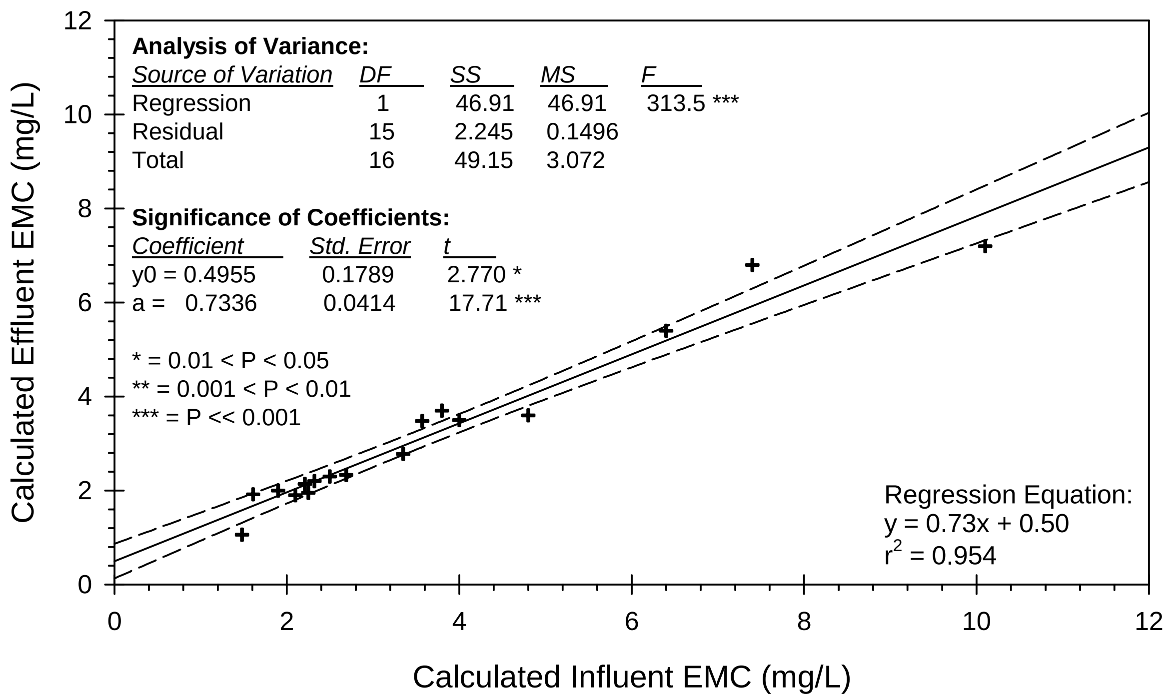

Figure 3. Total nitrogen EMC data extrapolated from available TK-N and NO_3^--N data for the KMMS StormFilter system with coarse perlite/coarse zeolite cartridges with a design flow rate of 15 gpm/cartridge. Using the regression of EMC performance evaluation method, total nitrogen removal is estimated to be 27% (P=0.05: L1=35%, L2=18%).

Discussion

The relationship observed between the influent and effluent EMC data shown in Tables 1, 2, and 3 is surprisingly linear considering the range of potential variables that affect system performance in the field. The validity of the linear relationships and the regression equations is verified by the very low probability (P<<0.001) of a type I error (the probability that the linear relationships are falsely identified and that no observable relationship exists). This suggests that as with the total suspended solids removal efficiency of the StormFilter, the TK-N, NO_3^--N, and possibly total nitrogen removal performance of the StormFilter is constant regardless of influent contaminant concentrations.

Though NO_2^--N concentration had to be assumed to be insignificant in order to extrapolate total nitrogen EMCs, the assumption has weight given the fact that NO_2^--N concentration is usually much less than NO_3^--N concentration. Thus an assumption was made in order to utilize the invaluable data provided by the KMMS StormFilter monitoring project. Other than NO_2^--N, all other important forms of nitrogen were accounted for.

Again, under the assumption that TK-N and NO_3^--N represent the bulk of total nitrogen load encountered by the KMMS StormFilter system, the positive TK-N and NO_3^--N removal performance demonstrated by the system indicates a net removal of part of the total nitrogen load to the system. Considering that biological denitrification is usually responsible for the removal of oxidized nitrogen in natural systems, this suggests that an underappreciated biological component was active within this engineered system. Much like the denitrification processes at work in the bed of a fluvial system, moist conditions, anaerobic microsites, and the ready availability of oxidized nitrogen may have sustained a population of denitrifying microorganisms within the system throughout its use. Considering the net removal of oxidized nitrogen from the system (between 4% and 39% with 95% confidence), and the absence of an intentional physicochemical oxidized nitrogen removal component from the StormFilter system, it can be said that the KMMS StormFilter system demonstrated some degree of biological denitrification throughout the 3-year monitoring period.

While the KMMS system did contain cation exchange media in the form of zeolite, the effectiveness of the media on NH_3-N removal could not be evaluated. The TK-N data includes, and thus accounts for, any NH_3-N present in the system; however, the fraction of TK-N present in the form of NH_3-N was not determined for influent/effluent sample pairs. Based upon the wide-spread, specific use of zeolite in the aquaculture industry for NH_3-N removal, it can be said that some of the TK-N removal demonstrated by the system was most likely due to the cation exchange media.

Conclusions

The analysis of 3 years of winter/spring monitoring data shows that the KMMS StormFilter system demonstrated a net removal of total nitrogen from stormwater originating from a road equipment maintenance facility. The total nitrogen removal efficiency of the system was estimated to be between 35% and 18% with 95% confidence.

The total nitrogen removal performance estimated by this study is thought to be conservative. This is based upon the observation that the bulk of the solids found within the KMMS system were observed to be organic, with recognizable leaf debris (Caltrans, 1999). It is impossible to account for the nitrogen load entering the system in the form of bulk leaf material using automated sampling equipment; however, this material eventually breaks down into smaller solids and even dissolved components that can easily be detected with automated sampling equipment upon leaving the system. Thus not accounting for this material on the influent end but accounting for it on the effluent end results in artificially depressed influent concentrations that negatively affect removal performance observations.

Considering the difficulty of accounting for nitrogen influx into a system in the form of bulk solids, as well as the potential environmental gains afforded by keeping bulk solids from degrading within a system, a very simple option may be exercised in the future. The screening of bulk solids can be performed at the intake for the system (usually catch basins) or within the system itself. In the interest of both accurate monitoring of the system as well as maximum total nitrogen removal, these devices could be cleaned between monitoring events and the nitrogen content represented by the bulk debris could be quantified. The only drawback to this activity is that it increases both the frequency and level of maintenance required for the system.

Stormwater360, Stormwater Management Inc, and Vortechnics Inc. are now CONTECH Stormwater Solutions Inc.

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Revision Summary

PE-C013
Document rebranded.

PE-C012
Document number changed; document rebranded; no substantial changes.

PE-02-001.1
Document reformatted; references updated.

PE-02-001.0
Original.

CONTECH STORMWATER SOLUTIONS INC.

Parameter Brief

The Stormwater Management StormFilter® for Removal of Dissolved Metals

Introduction

Urban Stormwater often contains high levels of soluble and particulate heavy metals. Generated from traffic, industrial facilities, and sometimes residential sources, these metals are frequently found in concentrations that are deleterious to aquatic life and other biota that are dependent on aquatic life as a food sources. Two of the most common metals found both in the water column and sediments are zinc and copper. Zinc tends to exhibit toxicity effects in the fresh water environment and copper exhibits toxicity characteristics in the marine environment.

Metals are measured as both total metals and soluble metals. Total metals are the sum of dissolved metals and those metals associated with particulates. Soluble metals are commonly defined as those metals that pass through a 0.45 micron filter. Frequently the soluble metals are in a cationic form in that they posses a net positive charge. However, sometimes the charge of the soluble metal has been satisfied in that it could be associated with sub-micron particles such as ligands or colloids. In this event, the metal may not have a net positive charge.

Cation Exchange

Cation exchange is the exchange of a cation (positively charged atom) for another cation. The process involves the displacement of an atom within the media matrix by an atom within the water column. The displacement occurs if the incoming atom's affinity for the exchange site is higher than that of the current occupying atom. In general, the physically smaller the ion (when hydrated) and the greater the positive charge the more tightly it will be held by the media.

Predictions can be made using a periodic table of elements for commonly found metals in stormwater runoff. Staying within the same row of the table and proceeding left to right produces an increasing affinity for cation exchange. This trend is promoted due to the metal atom remaining in the same valence state (charge) while the overall diameter of the atom decreases. Since the diameter decreases, the "apparent charge" of the atom increases, thus producing the driving mechanism for cation exchange. For most purposes the following affinity series is true:

$$Al^{3+} > H^{+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Fe^{2+} > Cr^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$$

Primary Exchange Ions within CONTECH Stormwater Solutions Filtration Media

The media-bound ions utilized with cation exchange filtration are calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) with calcium and magnesium being the primary exchange ions due to their abundance within the media matrix.

As presented above, zinc, copper and iron (as well as others) will force the displacement of the calcium and magnesium ions from the media.

Media promoting cation exchange and measured cation exchange capacity (CEC):

- CSF® media (93.8 meq/100-grams)
- Zeolite (125 meq/100 grams)

Performance Summary

Table 1. Soluble Metals Removal using organic media (CSF®, Metal Rx).

		Soluble Copper		Soluble Zn	
Site	**Media**	**Removal**	**Influent (ug/l)**	**Removal**	**Influent (ug/l)**
Nassco Shipyard	CSF	54%	61-401	64%	191-124
Charleston Boatyard	CSF	49%	11,000 (Total)	48%	3,560 (Total)
East Side Plating	Metal Rx	92%	58-268	43%	ND-569 (Total)

Table 2. Total Metals Removal

		Configuration (Removal efficiency)			
Parameter	**Influent (mg/l)**	**CSF Standard Grade 15 gpm**	**CSF Standard Grade 7.5 gpm**	**Perlite/Zeolite Coarse Grade 15 gpm**	**Perlite/Zeolite Fine Grade 15 gpm**
Total Copper	11	42%	49%	41%	54%
Total Lead	0.096	43%	47%	42%	60%
Total Zinc	3.56	41%	48%	31%	51%
Total Chromium	0.0384	49%	61%	57%	67%

Performance data has been summarized from field investigations (Table 1) and from laboratory (Table 2) investigations using captured stormwater runoff from the Charleston Boatyard.

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Parameter Brief

The Stormwater Management StormFilter® for Removal of Oil and Grease

Oils and Greases (O&G) are commonly found in stormwater runoff from automobiles and associated anthropogenic activities. O&G appears in many different forms in stormwater runoff: free, dissolved, emulsified, and attached to sediments. Total Petroleum Hydrocarbons (TPH) is the usual analytical measure of fuels, oils and grease (O&G) for stormwater. Typically the concentrations of TPH associated with runoff from streets and parking lots do not exceed concentrations that range from 2.7 to 27 mg/l (FHWA, 1996).

Frequently studies are conducted using high concentrations of oil, e.g. 5,000 mg/l in and 250 mg/l out, with claims of 95% removal. These concentrations are not representative of those associated with most stormwater runoff. In the event of these high concentrations, then an oil/water separation technology would be required as pretreatment.

Removal of TPH by media within the StormFilter cartridge is accomplished through adsorption. Adsorption is the attraction and adhesion of a free or dissolved contaminant to the media surface. This occurs at the surface as well as within the pores of the media granule. Adsorption requires that a contaminant come in contact with an active surface site on the media and time must be allowed for the contaminant to adhere. These reactions are usually promoted by polar interactions between the media and the pollutant. Adsorption can also occur within the dead end pores and channels of the media but is generally slower than a surface reaction due to limits of the contaminants diffusion into the pore. (Note: The contaminant's molecular size will limit diffusion in that the media's pore opening must be larger than the dissolved contaminant.) Commonly adsorbed pollutants include: gasoline, oil, grease, TNT, polar organics or organically bound metals and nutrients.

The media provided by CONTECH Stormwater Solutions Inc. for the removal of oils and grease are targeted to remove concentrations of 25 mg/l or less. Media promoting adsorption reactions are the CSF® leaf media, perlite, and granular activated carbon. For concentrations that continually are higher than 10 mg/l, an oil removing accessory such as a sorbent cartridge hood cover is recommended.

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STORMFILTER™

High efficiency / low maintenance stormwater filter.

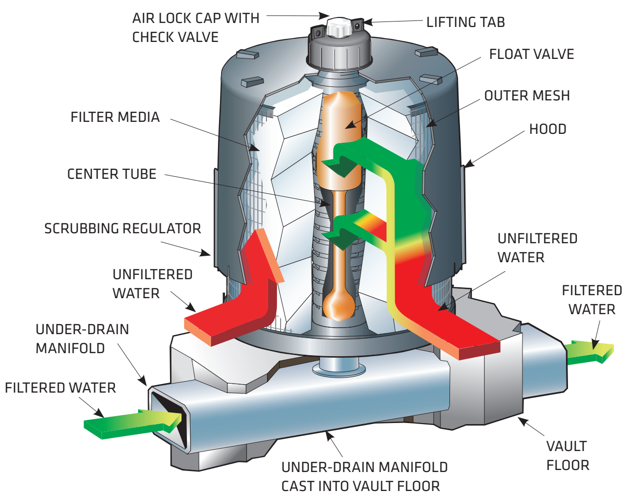
SIPHON-ACTUATED FILTRATION The Stormwater Management StormFilter® cleans stormwater through a patented passive filtration system, effectively removing pollutants to meet the most stringent regulatory requirements. Highly reliable, easy to install and maintain, and proven performance over time, StormFilter products are recognised as a versatile BMP for removing a variety of pollutants, such as sediments, oil and grease, metals, organics, and nutrients. These systems come in variable configurations to match local conditions and come with prolonged maintenance periods to ensure long-term performance and reduce operating costs.

HOW DOES IT WORK?

During a storm, runoff passes through the filtration media and starts filling the cartridge center tube. Air below the hood is purged through a one-way check valve as the water rises. When water reaches the top of the float, buoyant forces pull the float free and allow filtered water to drain.

After the storm, the water level in the structure starts falling. A hanging water column remains under the cartridge hood until the water level reaches the scrubbing regulators. Air then rushes through the regulators releasing water and creating air bubbles that agitate the surface of the filter media, causing accumulated sediment to drop to the vault floor. This patented surface-cleaning mechanism helps restore the filter's permeability between storm events.

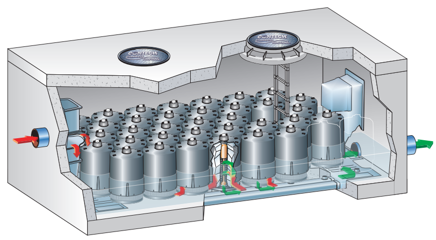
STORMFILTER CARTRIDGE



PROVEN PERFORMANCE

- New Zealand's only independently verified filter by Washington Department of Ecology, New Jersey Department of Environmental Protection and USEPA's Environmental Technology Verification program).
- Approved Auckland Council >75% TSS removal and approved on high trafficked roads (>20,000 V.P.D)
- Over 550 x StormFilter's installed throughout New Zealand-treating over 3.7 million m^2 of catchment area
- 8th generation of the product. Design refined and perfected over two decades of research and experience

STORMFILTER VAULT



STORMFILTER BENEFITS

UNDERGROUND SYSTEMS MAXIMISE PROFITABILITY

- Save land space allowing denser developments reducing sprawl
- Add parking spaces and increase building size, increasing profitability
- Compact design reduces construction and installation costs by limiting excavation

RELIABLE LONGEVITY & LOWER MAINTENANCE COSTS

- Self cleaning hood prevents surface blinding, ensures use of all media and prolongs cartridge life
- 1-3 year maintenance cycles
- 8 years maintenance experience – 1-5 year contracts with cost guarantees
- Minimal or no standing water. Lower disposal costs

CONTACT DETAILS

Stormwater360

FREEPHONE:
0800 STORMWATER
(0800 786769)

www.stormwater360.co.nz

Stormwater360® BETWEEN SKY AND SEA

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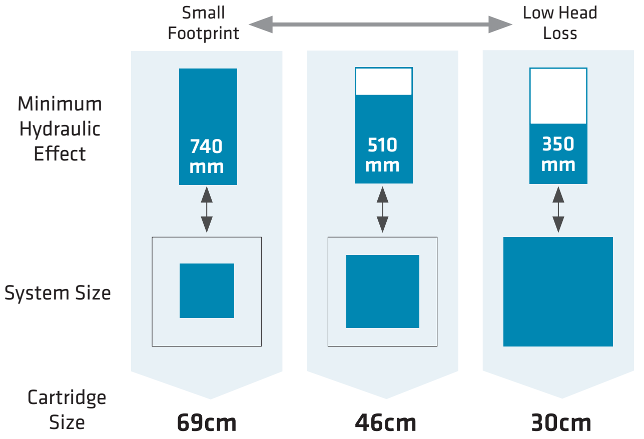
BETWEEN SKY AND SEA

SUPERIOR HYDRAULICS

Multiple cartridge heights gives design solutions for site restraints.



Other hydraulic benefits

- Low hydraulic effect as low as 350 mm head loss
- Zero surcharge of inlet pipe unlike upward flowing filters
- Can be operated with tail water e.g tidal conditions
- Online and offline configurations can limit hydraulic effects

MEDIA CHOICES

Our filtration products can be customised using different filter media to target site-specific pollutants. A combination of media is often recommended to maximise pollutant removal effectiveness.

Perlite is naturally occurring puffed volcanic ash. Effective for removing TSS, oil and grease.

ZPG™ is a multi-purpose media option approved for highly trafficked sites or sites with high metal loadings. ZPG is a mixture of Zeolite, Perlite and GAC (granular activated carbon). ZPG is ideal for removing soluble metals, TSS, oils and grease, organics and ammonium.

Zeolite is a naturally occurring mineral used to remove soluble metals, ammonium and some organics.

GAC (Granular Activated Carbon) has a micro-porous structure with an extensive surface area to provide high levels of adsorption. It is primarily used to remove oil and grease and organics such as PAHs and phthalates.

CONFIGURATION

Stormfilter's can be configured in any drainage structure. Please contact SW360 for a customised design.

PRECAST VAULT

- Treats medium sized sites
- Simple installation – arrives on-site fully assembled

DRYWELL/SOAKAGE

- Provides treatment and infiltration in one structure
- Available for new construction and retrofit applications
- Easy installation
- Shallow and Rock soakage models available

HIGH FLOW

- Treats flows from large sites
- Consists of large, precast components designed for easy assembly on-site
- Several configurations available, including: Panel Vault, Box Culvert, or Cast-In-Place

DETENTION

- Meets volume-based stormwater treatment regulations
- Captures and treats site specific Water Quality and Quantity Volume
- StormFilter cartridges provide treatment and control the discharge rate
- Can be designed to capture all, or a portion, of the WQv
- Detention vault configured to provide pre-treatment

CATCHPIT/ CURB-INLET

- Provides a low cost, low drop, point-of-entry configuration
- Treats sheet flow from small sites
- Accommodates curb inlet openings from 1 to 3 metres long

PRECAST MANHOLE

- Provides a low drop, point-of-entry configuration
- Uses drop from the curb inlet to the conveyance pipe to drive the passive filtration cartridges
- No crane required (Hi-AB lifting for most sizes)
- 1050-2400mm diameter sizes available